THE

BOOK OF GEOLOGY:

BEING

AN ELEMENTARY TREATISE

ON THAT SCIENCE.

TO WHICH IS ADDED,

AN ACCOUNT

OF

The Geology of the English Watering-Places.

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ETC. ETC.

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THE

BOOK OF GEOLOGY.

INTRODUCTORY CHAPTER.

OF what is the earth formed, and how are the materials arranged, are questions which must appear to many persons too difficult to be answered with certainty. They were proposed many hundred years ago by the philosophers of Egypt, Greece, and Rome, but the wisest of men were then unable to reply; but by the researches of modern geologists much information has been collected concerning the interior of the earth, and it is the object of this little book to answer the questions again proposed, with as great simplicity and accuracy as we are able, guided by the investigations and reasonings of modern science. It is, however, but little that can be known, for the opportunities of inves-

gation are confined to a small portion of the earth's substance. The depth, from the summit of the highest mountain to the floor of the deepest mine, is, in comparison to the entire body of the earth, much less than the skin of an apple to the fruit itself. The part open to investigation has been properly called "the crust of the earth," and that within it the interior. We are not in possession of any means by which we can absolutely investigate the interior of the earth, yet we may obtain some information concerning it, by examining the condition of rocks, the products of volcanoes, and the results of other physical phenomena.

In the following pages we shall have occasion to speak of the position of rocks, the organic remains contained in them, and the manner in which new mineral compounds are formed in the present day. But before we commence these inquiries, it may be desirable to allude briefly to a question which has been much agitated by modern authors, namely, the harmony of geological facts with the Mosaic account of the creation in the book of Genesis. The object of the inspired writer was evidently to assert the existence and Almighty power of the GOD he worshipped as opposed to the gods of

surrounding idolaters, for he commences his historical statement by the assertion, that, "in the beginning, GOD created the Heavens and the Earth." To what period he refers, by the use of the word "beginning," we have no means of determining, but it was certainly a period anterior to that which he calls the first day of creation; for the earth was then in existence, though "without form, and void," as we have the expression translated in the common version; but as it may be more properly rendered, "invisible and unfurnished;" for "darkness covered the face of the deep." Hence, it would appear that there was an interval between "the beginning" and the commencement of those seven days in which God is said to have resumed his power of creation and re-formation, prior to the existence of man. From a consideration of the statement made by the inspired writer we may estimate the period as of either long or short duration;—as consisting of a few days or thousands of years: but, from investigations into the constitution of the crust of the earth, it is certain that geological changes of vast extent and great moment were produced, and may, without presumption, in the absence of positive evidence, be referred to this period.

There have been, it is to be regretted, many learned and scientific men who have attempted to persuade themselves that the globe on which we live, and the universe of which it forms a part, were produced by chance; that the particles of matter were united by forces of a fixed character, and that their union in particular forms and conditions can no more be accounted for than the formation of meteorites in the present day. To persons entertaining such opinions, the questions may be put:—whence came these particles? and who invested them with certain forces? These, however, are not the opinions taught by geologists generally. They believe that an Almighty Being, the creator of all things, called into existence the globe on which we live, and that it came into existence in that state best suited for the accomplishment of His ulterior purposes; since that period, however, it has been acted on by various causes modifying and arranging the matter of which it was at first formed. To discover the nature and trace the operation of these causes are the objects of the geologist.

Sir Isaac Newton, whose name stands first among those who have attempted to under-

stand and explain the works of creation, entertained this opinion. "I believe," he says, "that GOD created heaven and earth; and gave unto them constant and perpetual laws, which we call of nature, which is nothing but the laws of the creation:—That the laws of nature, which now remain and govern inviolably till the end of the world, began to be in force when GOD rested from His work:—That, notwithstanding GOD hath rested from creating since the first Sabbath, yet, nevertheless, He doth accomplish and fulfil His divine will in all things, great and small, general and particular, as full and exactly by providence as He could do by miracle and new creation; though His working may not be immediate and direct, but by compass,—not violating nature, which is His own laws upon His creatures."

When a new and unexpected natural appearance is presented to our notice, we immediately ask (if we are anxious for information), what is the cause of this? and those who have studied the peculiarities of nature refer it at once to some agent, such as heat, light, electricity, or motion, according to the character of the appearance. In thus

speaking of the origin of natural things, it is not intended to convey the notion that these agents are independent causes, but causes previously arranged and directed by GOD, the author of all existence. This is a subject of so much importance, that it is necessary to dwell upon it more at large, for the purpose of illustration.

When the wind is high, the surface of the sea is agitated and driven into alternate elevations and depressions; but when the wind ceases, the waves sink, and in a short time the water becomes as smooth as a polished plate of metal. Why? the reader may ask: and we answer, it is a law of nature, that the surface of all fluids should be level. If another question be asked—why is it a law of nature, that the surface of a fluid is level? or, in other words, why does the earth have this influence upon fluids? We reply—it is the will of GOD; it is a principle upon which he has established the existence of fluids. The appearance, then, is the result of a law established by the Creator, when he formed matter, and called into operation the varied agents which act upon it.

The term "law of nature" may perhaps

require some farther explanation. We speak of the laws of nations, moral laws, and divine laws; but in all these instances, we give a different meaning to the word than is intended in the expression, "a law of nature." A divine or human law is a command which we are required to obey, or suffer the penalty annexed; for the existence of a power capable of enforcing obedience by inflicting punishment is presupposed. A parent or master may make laws to govern his family or household, because he has power to enforce them by punishment; but a schoolboy cannot make a law to regulate his master, or a child one to restrain the parent; for neither of them have any means of enforcing that which they may desire.

A law of nature is essentially different in principle from a law regulating moral action. When God created matter, he endowed it with certain properties, placed it under the influence of various agents, and established laws which it must obey under all circumstances. So constant is the action of these laws, that we may even determine what will result from certain conditions of matter before the effect is seen. All science, then, consists in a knowledge of the laws of mat-

ter, and in deductions drawn from them. This statement will, perhaps, be rendered more evident by an example.

When earthy particles are mingled with water, and the liquid is allowed to remain at rest for a short time, they will, supposing them to have a greater density, be separated, and a sediment will be formed. This would happen if the experiment should be made in an earthen or metal vessel, and the same effect may be observed in a natural basin, such as a sea, a lake, or a river; which are, in fact, valleys filled with water. It is, then, a law of nature that the solid particles of matter suspended in a liquid having less density should, when the fluid is at rest, be thrown down; and it is for this reason that sediments are formed.

It has sometimes happened that violent earthquakes and volcanoes have left dry the beds of rivers and lakes, and by exposure to the air, these sediments have dried, and become perfectly hard beds, and presented the appearance of rocks, such as are seen in various countries. Scientific men have, therefore, been led to the conclusion, that beds of clay, sand, and other substances which may be

found in almost every district, were produced by sediment, and that they were either raised *into the air by volcanoes and earthquakes, or were left dry by the receding of the water,* at one time covering them. Hence then, it will appear that much of that which we call our knowledge of the earth is in fact nothing more than a series of deductions drawn from the laws of nature. This kind of knowledge is most valuable, but great care is required in forming our conclusions, for a single mistake may mislead us, and cause the adoption of many errors as established facts.

Another example of the collection of knowledge by deduction may be given. In walking over a country far away from the sea, and even from any large body of water, the reader has perhaps found the shell of a sea fish. Now, it is certain that the shell once contained a fish, and the fish could only have lived in the sea; the shell must, therefore, have been either brought to the place where it is found, or the sea must, at some time or other, have covered the spot, though now far distant. But it may have also been observed, that the rocks themselves contain a large number and variety of shells, a circumstance

which precludes the supposition that they were brought to the place by the hand of man; and as they are intermixed with the mass of rock, there is reason to believe the sea once covered the spot, and deposited both the rock and the shells.

Again, large trees have been found, as well as leaves, fruits, and other vegetable productions, converted into stone, or, as it is otherwise expressed, petrified. We cannot suppose this to have been the original state; there was a time, when the tree was attached to the soil, had its roots, branches, and leaves; there was a time when all its sap vessels were perfect, and the vegetable juices were circulating through them. The conversion into stone must, therefore, have happened from causes altogether distinct from those by which its existence was preserved, and it probably occurred at the time when the rock containing it was deposited.

From these few introductory remarks, then, it will appear, that God, having created matter, gave, when he called it into being, certain properties, and regulated its states and conditions by fixed laws. From these laws, it is impossible for matter to escape; they are con-

stant, and, without the direct interference of the Creator, are incapable of change. By a knowledge of these laws man, endowed with a power of investigation and thought, is able to trace the operations of his Maker in all the varying features of nature. Connecting facts together, he may discover things before hidden from his view, and enlarge his acquaintance with the works of the Almighty. Geology is a science that is not confined to the past; it presents to our view the state of the earth at different periods of her history. The records of former revolutions are written on its substance, and by deductions, drawn from present appearances, past conditions may be determined.

All scientific knowledge is valuable to the possessor, not only as a source of mental improvement, and as a satisfactory amusement, but also as a means by which a view of the wisdom and power of God may be obtained, and the moral and physical happiness of man be augmented. The study of any branch of philosophical knowledge is calculated to give a higher tone of intellectual enjoyment than that possessed by mankind generally. With some minds this would not be a sufficient

motive for the study; they must have some proof of its applicability to their own wants, or of its usefulness in the accumulation of wealth. Although we have no kindred feeling with the persons who entertain these opinions, we admit the importance of giving, as far as pos*sible, a practical tendency to our studies,* so as to improve the state of society at large; either by diminishing the amount of bodily exertion, or by providing comforts to meet the necessities of humanity. Both these effects have followed the study of geology.

To a people who are living in a wild and wandering state, the science of geology would be of little value; though some knowledge of the mineralogical characters of the district they inhabit would still be absolutely necessary. But when a community is formed, when men begin to congregate together, and choose a locality as their home, a division of labour is required, and wants are called into existence that were not before felt. The arts spring up in the midst of them, and a knowledge of minerals and rocks is sought out. Tools, and machines of various kinds, are required; and, unable to find any suitable materials in the vegetable productions,

they commence the examination of the mineral. Iron is perhaps found, and its properties discovered; but to make the discovery available to the purposes of the community, fuel is required, and especially that kind found in the bowels of the earth, called coal. Here, then, are *two substances, iron and coal, without which* no extensive manufactures can be carried on, and to which this country is much indebted, for its station among surrounding nations. We can scarcely conceive a more certain cause of destruction to all our commercial prosperity, than an ignorance of geology. By it we are taught how to ascertain the probable existence of rocks that are not seen, and even to fix upon spots where the substance we require may be found; without it we should be ignorant of those minerals most required for the support of our wants, and only acquainted with those that appear at the surface.

Geology then is a study worthy of our consideration, whether as regarded as a subject of deep interest to every mind capable of deriving pleasure from the works of creation, or as affording a means of procuring those mineral substances useful in the arts and of economical

importance. We are living in a world which has in all probability been in existence for many thousands of years, called into being at some period long past, denominated in Scripture "the beginning." Since this time it has been acted on by various causes, some of them being of immense force. Mountains have been up-heaved, continents elevated, rocks broken up, deposits formed, and whole generations of animals destroyed. Geology brings all these catastrophes before us, withdraws the veil that hides the past, and presents to our imagination scenes differing so much from what we now witness that without its aid they could not have been conceived.

In this book it is our intention to explain first the composition of the crust of the earth, and then to trace the nature and influence of those agents which, still acting upon mineral substances, are in the present day destroying and re-producing rocks. These are the two heads under which all geological facts may be classed.

To give a general, but clear description of the most important principles is all we shall attempt. The science is extensive, and consequently difficult, comprehending a knowledge of mineralogy,

botany, and *zoology*. There are, however, but few geologists who possess so much information as to be thoroughly acquainted with all these sciences, and those who read for general information will, it is hoped, find something to please and much to excite fresh inquiries in the following pages.

CHAPTER I.

THE CRUST OF THE EARTH.

The Earth composed of many Minerals. The necessity for these. The Earth created for man. Arrangement of Rocks. Rocks give a character to districts. Early history of Geology. Werner. Stratified and unstratified Rocks. Peculiar Stratification. Difficulty of tracing Strata. Unstratified Rocks. Mountains. Connection of Mountains. Elevation of Mountains. Periods of Elevation. Valleys. Upland and Lowland Valleys. Valleys of Elevation and Denudation. The Deluge. Geological Periods.

It has been already stated that the portion of the earth open to investigation is called the crust or covering. It consists of a great variety of substances, as every one knows. In Scotland, and in some parts of both the north and south of England, a rock called granite is found; it is that stone with which the horse-roads of London and other large cities and towns are paved. In some parts of Wales, Cumberland, and Devonshiré, slates are obtained; a very useful mineral employed for covering the roofs of houses and

many other purposes. In Cornwall the miner finds metals; and in the island of Portland that stone used in London for foot pavements. In other places, minerals differing from either of these are discovered, but none are perhaps more frequently obtained than clay and sand. There is also a great variety of clays and sands; some clays may be used for making bricks and tiles, others are altogether unfit for such a purpose. The part of the earth examined by man is then composed of a variety of substances, a wise provision by the Author of all good for the support and advantage of his creature, man.

The comforts by which we are surrounded depend on so many circumstances, that an alteration in one or two of the arrangements of nature would render the earth unfit for the supply of our wants. Let us for instance suppose the earth, or at least that part of it open to our investigation, to have been formed of clay, one of the most useful of all mineral substances, and what a different creature would man have been to that which he now is. Destitute of coal, many places which are the scenes of industry and plenty, and support a large population, would have been positively uninhabitable, and the human species would necessarily

have been confined to warm climates, or those which afforded the greatest quantity of wood for fuel. The utensils and instruments now so admirably suited for the purpose to which they are applied must have been formed of burnt clay or hard wood, neither of which would have met our wants. It is true that for many purposes earthenware may be used as a substitute for metal, but there are a multitude of domestic and manufacturing operations in which no other substance could be employed. What, for instance, could supply the place of iron, in the construction of stoves, boilers of steam-engines, and the tools used in the mechanical arts, as well as in agriculture. Stones of various degrees of hardness are also necessary to man for the accomplishment of the many devices and plans by which he proposes to lessen his labour, or increase his wealth and comfort. Man is a being so constituted in mind, and in physical power, that his invention and ingenuity would have remained dormant, and even have been entirely lost, had not materials been provided by which he could apply his qualities of mind to the accomplishment of useful purposes.

From all the arrangements of the physical

world we may learn that matter was created and set in order with a view to the sustenance of animated being. Every discovery, opening to our view a wider field of enquiry, establishes this principle; and so fully, we are sometimes inclined to believe every particle has its destination in the support of life. It has also been so in the former eras of our earth's chronology, and although many races are extinct, their destruction has perhaps, been necessary to prepare the earth for the residence of man. But, however this may be, the adaptation of the earth to the physical constitution and intellectual power of man is an evidence of the purpose for which all past revolutions were ordained.

When we walk by the sea side and see the immense number of shells accumulated on the shore, we cannot but call to mind that on other shores there are similar accumulations, and we feel at once that it would be vain to attempt to express a number equal to that of the animals whose remains lay heaped on the margin of the ocean. But if we take a handful of the sand with which they are mingled, and examine it by the aid of a microscrope, we discover millions of shells which escaped the observation of the unassisted eye. Still more sur-

prising is the discovery recently made by Professor Ehrenberg of Berlin, that tripoli, a substance used in polishing metals, is entirely composed of the cases of infusoria. According to the calculation of this naturalist, there are forty-one thousand millions of one species in every cubic inch. Tripoli is found in large beds in several parts of Germany, but at Bilin in Bohemia it has a thickness of fourteen feet, and spreads over a considerable surface. The number of organic remains in this single stratum is therefore, to us, verging on the infinite. But this is not the only rock formed almost entirely of the remains of organized beings. It is supposed by some geologists that chalk is composed of the detritus of shells which once belonged to marine animals, and the opinion is daily made more probable by new investigations.

ARRANGEMENT OF ROCKS.

One of the first objects of a student must be to ascertain in what manner the various substances composing the crust of the earth are arranged. It is not sufficient that there should be materials within its surface fit for the use of man; to render them available, they must be

brought within his reach. This has been done in a remarkable manner, and by causes which might have been supposed incapable of producing such benefits. We have been endeavouring to ascertain what opinions would be formed concerning the arrangement of rocks, without any farther information than that derived from such a casual examination as most men give to the district in which they happen to live. We have endeavoured to divest our minds of all the opinions derived from a perusal of many geological works and careful study, and to judge of things by their appearances, but the elementary principles were so early impressed on our memory by a passionate attachment to the science, acquired by accident, that we are unable to find any other reason for the crude notions usually expressed than a want of examination and thought.

A limited investigation will prove that the beds composing the crust of the earth are not arranged like the coats of an onion. If such were the case, the same rock would be found at any place on the surface of the earth, and this, as the reader well knows, is not the case. If we suppose it to have been broken in some places by the elevation of

mountains, the eruption of volcanoes, and by earthquakes, it would still be found in the valleys. Many persons believe that the mineral masses are crowded together without any arrangement, and that it is a mere matter of chance that a sandstone is found in one place, a clay in another, and a gravel in a third. But this is the hasty conclusion of an inexperienced and casual observer, and is not only opposed to the view we have taken of the object of material existence, but is disproved by a more extensive investigation.

Many persons who have written about rocks have said that they have a constant order, and are never found out of a certain position. This statement is true, but is liable to be misunderstood. When it is said that rocks are arranged in an order which is never broken, the reader must not suppose that limestone can only be found in one situation, sandstone in another, and clay in another. Geologists class a number of beds together, and it is of these combinations of beds, called formations, they speak. Clay and sand may be found in nearly all, but there are certain rocks which belong to one situation exclusively. Granite is said to be the lowest of all the rocks, and when it appears at the

surface, the evidence of great disturbance may *be always traced in the surrounding districts.* Chalk, slate, and the stones used in building, have also their fixed places; so that an observer, who is acquainted with the science of which we speak may from an examination of a country determine with accuracy whether any of these substances could be found by digging or boring.

The appearance of a country depends on the nature of the rock composing it. Singular as it may appear, a person who is accustomed to the features of a district, and to the examination of the mineral masses, can with tolerable certainty predict what will be found beneath the surface, from the form of the surface itself.

A mountainous country, with almost perpendicular peaks of bare rock, fearful chasms, stupendous walls, and here and there immense detached masses, give evidence of what are called primary, and in all probability granitic rocks. The gently undulating and smoothly turned hills, as if a flood had passed over them, and washed or worn away all the rough projecting masses, intersected by rich valleys, and

covered with a delicately green herbage, are *almost as certain evidences of chalk. By features not less striking, the practised eye may distinguish other formations before an examination is made.*

A Geologist who has been accustomed to observe rocks may ride through a country with a good map in his hand, and afterwards be able to explain with some precision its formation and character.

RISE OF THE SCIENCE OF GEOLOGY.

Men have always been curious to know something of the earth on which they live, and in the absence of practical information have endeavoured to satisfy themselves with vague and even monstrous hypotheses. Every nation of antiquity has had its cosmogony; and it is a singular fact, that although modern investigation has shown their inaccuracy and folly, it has also disproved the arguments which were once urged against the description given in the first chapter of the book of Genesis, "the accuracy of which," says a modern author, "has been demonstrated by the most recent observations of Geology;"

or rather, as we should say, by the agreement of which with our enquiries, we have reason to believe that our conclusions are accurate.

It was not till the commencement of the sixteenth century that a spirit of observation sprang up, and threatened to supersede the wild theories with which those who made a pretence of knowledge were satisfied. Agricola, a Saxon miner, laid the foundations of the science of mineralogy, and the art of mining. Bernard de Palissy, a potter, assured the French Academy that the fossil shells which had been thought mere imitations, had really been the abode of fishes; and Steno of Tuscany remarked the distinction between what are called primitive and secondary rocks.

"The end of the seventeenth century," says Baron Cuvier, "saw a new science arise, which assumed in its infancy the proud name of the 'Theory of the Earth.' Setting out from a small number of ill-observed facts, connecting these together by fantastical suppositions, it pretended to remount to the origin of worlds; to amuse itself, as it were, with them, and to form a history of them. Its arbitrary methods, its pompous language, all seemed to disunite it from the other sciences; and in fact, philoso-

phers by profession excluded it for a long time from the circle of their studies.

"At last, after a century of ineffectual attempts, it has entered within the limits assigned to the human mind. Two celebrated men, Pallas and Saussure, had prepared the way for this happy reform; a third has accomplished it; I mean Werner. With him the most remarkable epoch of the science of the earth commences; and we may even say that he alone has filled that epoch. For he has had the good fortune to see those ideas which were so novel, and those views which before his time were so unknown to naturalists, universally prevalent during his life. He has left as many inheritors of his methods and his doctrine as there are observers in the world; and wherever mines are explored, or the history of minerals is taught, some distinguished man is to be found, who boasts of having been his disciple."

Werner was born at Wehran, in Upper Lusatia, in the year 1750. His father was the director of a forge, and from a child he was accustomed to amuse himself with the splendid minerals given to him as playthings. At Freyberg he attended a course of lectures on metals, and the method of preparing them for com-

merce; and at the University of Leipsic he *studied law. Both these subjects were in some* degree necessary for his intended pursuit, as a superintendent of mines, and they certainly contributed to form the peculiar characteristics of his mind. "Two tastes—we might even say, two passions—attended him through life; the love of minerals, and the love of order. He was fond of dividing and of classifying objects, as well as ideas. He was pleased with all those things which could be disposed in regular order."

Considering how much Geology is indebted to Werner, it will not be out of place to introduce a few other remarks on the peculiarities of this great man. "He talked as much as any one desired," says Cuvier, "and his conversation was always that of a man of genius, as well as that of a man of kind feeling. During whole hours he could develop the boldest and best connected ideas, but it was impossible to make him take up the pen. He had an antipathy for the very mechanical art of writing, an antipathy, the very excess of which rendered it amusing. His letters were extremely few; the most tender friendship, the most profound esteem, could scarcely draw one from him; and

to avoid reproaching himself with his want of *politeness in this respect, he at last did not even open those that were addressed to him.* A certain author, who wished to consult a great many philosophers respecting a voluminous work, had circulated his manuscript. A packet was missing during this journey. After a thousand researches it was disinterred at last from among a hundred others in the possession of M. Werner. To crown all, I may notice, that he has never replied to the Academy since it placed him in the list of its eight foreign associates, among whom all the greatest names that have illustrated Europe for a century are found; and, perhaps, he might never have known that he had obtained this honour if he had not learned it from some almanac."

In the year 1775, Werner was appointed professor and inspector of the cabinets at Freyberg. His first work was that of establishing a language or nomenclature, by which minerals might be described. This being completed, he commenced the arrangements or classification of minerals, and then devoted himself to an examination of the order of rocks, and so great was his success, that he may be considered as the father of Geology. Although Werner wrote

but little, he spoke much, and by his lectures prepared many young men to prosecute his enquiries, and stimulated them by his own enthusiasm to follow in his steps. Humboldt was one of the first to commence that course of enquiry suggested by his tutor, and visiting Europe, Asia, and the Americas, collected a vast amount of information that has done much to give a precision and accuracy to our views and opinions. Many other observers of great talent have been since engaged in similar investigations, and we shall now endeavour to give the reader a brief account of the results of their labour.

STRATIFIED ROCKS.

When rocks are divided into beds the upper and under surfaces of which are nearly parallel, they are said to be stratified. To illustrate the meaning of the term, we may compare stratified rocks, in an undisturbed position, to a series of boards, of any material, placed on each other horizontally, or at any angle to the horizon, or to books piled one upon the other. The position of strata varies greatly, taking all the intermediate directions between the horizontal and vertical.

Figure 1, Plate 1, is a representation of a series of stratified rocks in a neighbouring island. They are not, as will be at once evident, in the same state as when deposited by the ocean, but have been tilted from their horizontal to a much inclined, and nearly vertical, position. No series of beds can be, strictly speaking, called parallel, for not only must a sediment from a body of water fill the depressions of the surface on which it falls, but also be acted upon by a variety of disturbing causes, such as eddies and currents. It is also worthy of notice, that a stratum can scarcely be expected to have the same thickness throughout its extent, for it will in almost all cases "thin out," so that the strata which it in one place separates will in another be in contact. This may account for the absence of certain beds belonging to particular formations in some situations and their full development in others.

It is not always easy to determine the dip of strata, and the inexperienced observer especially will find it necessary to guard himself against deception. It will be readily perceived by a slight reflection that a series of beds may appear perfectly horizontal on one face and yet have a considerable dip on another. Thus, in walking at

the foot of a high cliff consisting of several rocks piled one upon the other, we may at first be led to the supposition that they are undisturbed because the face presented to us, or, to use a technical expression, the *strike*, is horizontal; but should we at any place have an opportunity of examining a section at right angles to that we had before seen, we shall in all probability discover that the beds have a considerable dip.

Instruments have been invented to enable the observer to measure the dip with great accuracy; but although in every geological survey it is of the greatest importance to ascertain the dip, as the only means of understanding the formation of a district, a greater accuracy than that which may be obtained without the assistance of instruments is rarely necessary.

Strata are sometimes curved. When a bed presents an appearance as if forced up by some rock rising from below (as in Figure 2, Plate 1,) it is said to have a saddle-shaped stratification. When it takes that form represented in Figure 3, Plate 1, it is said to be basin-shaped. This is the form in which the coal beds are usually found.

In a mountain, or any other natural section of rocks, lying in their undisturbed order, the lowest and highest may be easily distinguished. But when the strata have been contorted this cannot always be done with ease.

Thus, in Figure 4, Plate 1, which represents a natural section of rocks, it would be difficult for a person unacquainted with Geology to ascertain the order by walking from *c*, over the hills, to *d*. The mass *c c* is a rock of one kind, and it will be found to compose the hill as the traveller ascends, but on the top he will find a rock of another description. After crossing the summit *a* of the hill he comes again upon the rock he first observed, and then upon one, *b*, which differs from both. That part of the cliff from *c* to *d* is formed of a fourth kind, and the observer will find it just before he comes on the second mass *b*. The patches *a a* resting on the summits of the hills are called out-liers or mountain-caps, and those in the hollows, up-fillings. It is easy to understand the arrangement when represented on paper as in the drawing, but most young geologists would be puzzled to make out the construction of a district so formed. A full and careful examination is first required, and after this he should endeavour to represent on paper what he has observed in

nature, and in this way he may solve, with a necessary degree of caution and perseverance, all the difficulties he will meet with. The probable origin of this appearance we may also trace. The rock *a a* at one time covered the masses *c* and *d*, by their elevation; for the direction of the strata being nearly perpendicular shows that they have been disturbed, a large portion has been broken, and the fragments were in all probability carried away by a flood of water. The rocks *b b* have been formed by deposition from water since that period.

This short description of the arrangement of stratified rocks will enable the reader to account for many of the appearances he observes in those countries with which he may be made acquainted by personal examination. It will, however, be constantly necessary to refer to the action of internal agents. The matter composing many of the hills and mountains was raised to the surface after the formation of the stratified rocks, the proof of which may be gathered from the broken, dislocated, and irregular appearance of the beds.

Some rocks also are evidently of volcanic formation, having been thrown to the surface of the earth in a similar manner to the modern

lavas. There is much interest in the examination of these curious products, not only for their remarkable influence on the districts where they occur, but also, for the beautiful forms they sometimes present. They have been distinguished by geologists as the unstratified rocks, and are extensively distributed over the surface of the earth, being associated with all the various kinds of stratified masses. There are two situations in which they are presented to our notice;—upon the surface overlying aqueous formations, and in fissures, in which state they are called veins. The columnar structure of some unstratified rocks must be familiar to all our readers from the representations of the Giant's Causeway and Fingal's Cave; of these unstratified rocks we shall speak more fully in another part of this book.

MOUNTAINS.

Much of the interest with which we view the surface of the earth arises from its diversity of form and elevation. The same variety must exist at the bottom of the sea as upon dry land. In some places there are extensive plains, and

so near to the surface of the water as to impede navigation; these are called shoals, while others are covered by a great depth of water. These vast plains, like those on dry land, may contain deep *hollows*, of which there are many on the eastern coast of Scotland, called the Montrose pits. Mountains and valleys also exist in the bed of the ocean, and sometimes the former are sufficiently lofty to rise above the surface of the water, and form islands. Of this statement we have evidence, and, indeed, the basin in which the water is contained, is but a continuation of the land. If we could take a view of it we should find it to vary but little in character from the dry land, having its mountains and valleys with their own particular vegetation, supporting different species of animals.

From some curious calculations, founded upon known laws, it is supposed that in some situations the sea may be as much as 30,000 feet in depth; and there are many spots where the navigator has been unable to find a bottom. This cannot always be attributed to the shortness of the line, for the momentum of the water may carry it away and prevent a perpendicular measurement. Mr. Scoresby once found a bottom in the Greenland sea, at the depth of 4,700 feet

below the surface, and this was the greatest depth ever measured. It is a fact worthy of notice, that in those places where the coast is precipitous and rocky, the sea is frequently very deep close to the shore; and on the other hand the water is comparatively shallow round those shores which gradually decline to the sea.

The highest portions of the earth's surface are called mountains, the lower hills, and the depressions valleys. These, however, are but relative terms, and the reader may ask to what level do writers refer when they speak of elevations and depressions. The height or depth of any object must be estimated by the situation of the place from which we view it. To have some constant level from which to estimate all heights is therefore of the greatest importance. This we have in the surface of the ocean, which although occasionally disturbed by winds, and thrown into a state of irregularity and almost uproar, and by tides, still offers a means of calculating the relative heights of all places on the dry land. The waters of the ocean are under the control of laws with which man is acquainted, and to them, all its changes may be traced; and from a knowledge of them,

combined with some ascertained facts, its changes may be predicted. The ocean is, speaking generally, perfectly level, and yet there are exceptions, spots where the water is raised above the general level. Thus, for instance, the easterly trade winds drive the water towards the African coast, and causes the Red Sea to have a constant height of about twenty feet above the surface of the ocean. So again, the evaporation from the Mediterranean draws away more water than is received into that basin from the numerous rivers which flow into it, causing it to have a lower level; so that there is a constant supply rushing in through the Straits of Gibraltar. But although there are these exceptions to the rule, it is perfectly true as a general statement that the surface of the ocean is level; and from it all elevations and depressions are measured.

Mountains have a great variety of forms, but are commonly more or less conical. "But this ordinary outline," says Mr. Bell, "assumes various modifications, especially in very high mountains, which sometimes shoot into the form of enormous crystals, or appear crowned with a vast and rocky battlement, or present a highly fantastic outline of naked rocks, heaped

and crowded upon each other in every position. *These appearances are called needles, peaks, teeth, domes, forks, and horns,* according to their supposed resemblances; and this difference of outline is thought by some Geologists to indicate a difference also of internal structure and composition. When a mountain rises into two ridges at the summit, with a circular hollow between them, it is said to have a saddle ridge. When the highest ridge is divided into a number of distinct teeth, it is called a serrated ridge. The deep rugged excavations formed in the sides of the mountains by the descent of streams are called ravines, and the extensive hollows which occur between chains of mountains are denominated valleys. Mountains which rise from the plain at an angle below 45 degrees, are considered as having a gentle inclination; in proportion as the angle exceeds 45 degrees, the ascent is said to be steep. The greater number of mountains have one of their sides very steep, while the other presents a gradual slope. Thus the Pyrenees are steeper towards the south than the north; and the Alps on the side of Italy, than that of Switzerland. The cause of this configuration is very obvious, when

we reflect that chains of mountains are frequently nothing more than the abrupt borders of highland plains. And hence with most of the chains of the globe, their steepest side is that which approaches to the sea. Thus the Himalaya mountains are steepest on the south-west sides, which front the Indian plains; and the Elboors are steepest towards the Caspian Sea."

A series of mountains united by the same base is called a chain, and a collection of these chains a system. A close connexion is known to exist between many of these chains, and, as some persons suppose, between all the systems on the surface of our globe. To illustrate this remark, the reader may examine on a map the direction of the Uralian mountains, and the chains with which they are united. There are however some mountains completely insulated, such as the rock of Gibraltar, but these are, for the most part, volcanic.

THE ELEVATION OF MOUNTAINS.

The attention of geologists has been for a long time directed to an examination of the various mountain chains, and indeed the first

principles of their science were discovered and tested among the ragged forms of the Alps. Von Buch discovered a long time since, that the mountain chains of Germany were not contemporaneous; but we are indebted to M. Elie de Beaumont for the proofs that they have not only been elevated at different periods, but also that those chains which were elevated at the same period have the same direction, or, in other words are parallel to each other.

Before we mention the various systems of mountains as observed by M. Beaumont, it may be desirable to explain the manner in which the geologist attempts to determine the periods of disturbance. To understand this description it is only necessary for the reader to bear in mind that rocks have a constant order, and that, although they may be absent from the position in which they are usually found, they are never seen in another part of the series. Thus, for instance, the coal beds lie upon a group of rocks called the Grauwacke group, and are covered by another series called the Red Sandstone group. Now, the Grauwacke may be absent, and the coal beds lie upon some rock lower still in the series, but the coal is never found below the Grauwacke or above the Red Sandstone.

Directed by this principle a practical geologist can always say with certainty when coal or any other mineral cannot be found, but he cannot with equal certainty say that it will, for it may be absent from the series altogether.

Figure 5, Plate 1, is a representation of a series of rocks; some of which have been evidently disturbed by internal forces. We have here rocks in three different states.

The central part *c* is the elevated mass, *b*, the strata tilted by it; and *a* undisturbed and horizontal beds. Supposing it were required to determine the period when the elevation and disturbance occurred, the geologist has all the evidence necessary to give an answer. We do not mean that he can fix the year or century, but the date in relation to other strata. The beds *a* are horizontal, and yet rest on the disturbed strata *b*: this could not have happened if they had been deposited when the elevation occurred. It is evident to every one, that if a number of books, or any other things of a similar form were resting on one another, it would be quite impossible to thrust up the lowest one without disturbing all those that rested on it. In the same manner it is impossible to suppose that the strata *b* could have

been raised without disturbing the beds *a* if they had been at the time deposited. The geologist cannot pretend to determine when the rocks *a* were deposited, but it must have been after the elevation of those on which they are now resting. The precision with which he can determine the period must depend on the character, or in other words, the relative position in the geological series of the beds *a*. If they should be in their natural order, no bed being wanted between *a* and *b*, the exact relative date will be known; and the degree of precision will decrease with the number of rocks which are known to intervene between them. In this way M. Elie de Beaumont has endeavoured to ascertain the periods when the mountain chains of Europe were elevated. There are, according to this observer, twelve systems, but as we have not yet attempted to describe the order of rocks or the mineralogical characters by which they are commonly distinguished, it would be useless to enumerate them.

"The fact of a general uniformity in the direction of all the beds upheaved at the same epoch," says M. Beaumont, "and consequently in the crests formed by these beds, is perhaps as important in the study of mountains, as the in-

dependence of successive formations is in the study of superimposed beds. The sudden change of direction in passing from one group to another has permitted European mountains to be divided into a certain number of distinct systems, which penetrate, and sometimes cross each other, without being confounded. I have recognised from various examples, of which the number now amounts to twelve, that there is a coincidence between the sudden changes established by the lines of demarcation observed in certain consecutive stages of the sedimentary rocks, and the elevation of the beds of the same number of mountain systems.

"However strongly it may be established by facts," says M. Beaumont, in another place, "that there have been, during the formation of the crust of the earth, a long series of tranquil periods, separated from each other by a sudden and violent convulsion, by which a portion of the earth's crust was dislocated, or in other words, that the surface was ridged by the elevation of mountains at different periods, the mind cannot rest satisfied without finding, among the causes now in action, a force, capable of producing disturbances different from those which we now witness." The author then goes on to

state, that the elevation of the mountain chains *cannot be referred to volcanic action*, and attributes it to the slow cooling of the earth, supposed to have been, at one time, even on its surface, intensely hot; but it would not be profitable for us to enter into an examination of these thoretical opinions in this introductory work.

VALLEYS.

We must now proceed to enquire into the most remarkable phenomena in reference to valleys. The word valley has not been very accurately defined; in one sense, every depression on the earth's surface may be called a valley, but the term may with propriety be confined to those depressions bounded on two or more sides by hills or mountains. If we were to take the former definition, ravines and gorges would be included among the valleys. A ravine is a deep depression or fissure, bounded by perpendicular walls of rock, and are common in both mountainous and lowland countries, frequently appearing in situations where they could not be supposed to exist. Taking the restricted and more proper definition of the word valley, we will endeavour to give a brief account of the

peculiarities of form presented by these depressions, and of their probable origin.

Valleys have been sometimes divided into two classes, an arrangement founded on their relative elevations. Mountain valleys are those which cross, or run in the same direction as mountain chains; and are generally characterised by rugged and precipitous sides, usually terminating in lofty pinnacles, or broken masses of rock. Their singularly wild features, occasioned in all probability by the manner of their formation, are heightened, rather than subdued, by the influence of existing agents, such as frosts, mountain torrents, and atmospheric causes. These agents, however, by their continued action on rocks, break down and crumble large masses, producing accumulations of fragments or sediments, called, by geologists, *detritus;* and this being deposited in favourable situations ultimately affords a soil adapted for the growth of vegetables, and ultimately of large trees. Hence it is, that we frequently find in the most desolate mountainous regions spots of verdure; but should there be no places where the detritus can accumulate, the torrents and the rocks carried down by them, will but add to the wildness of

the scene, by wearing or breaking away the masses which impede their progress.

The features of lowland valleys are much less striking. They have usually a gentle undulating form, and even in the course of years suffer little or no alteration from the action of atmospheric causes, except when violent floods sweep over their surface.

Some eminent writers have maintained that all valleys produced by the action of water, have been formed by the steams which flow through them. That this has been the case, in some instances, we do not doubt, and in all the agency of rivers has been great in modifying their forms. But many, and perhaps, we might say, the greater number of valleys are to be principally attributed to the dislocation or breaking up, by some violent lateral force, of the beds forming the district, and the subsequent washing away of the loose materials.

Mr. Young in his Geological Survey of Yorkshire, has given an interesting example of this, to which we may allude. "The Esk," he says, "did not cut its way to the sea through our rocky cliffs, but its channel was opened by a vast break in the strata, and by the washing away of the loose materials, disengaged by the

shock which this dislocation produced. The river may have filled up some hollows and inequalities of its original channel; but it cannot have excavated those extensive and diversified dales through which it runs. This is evident from the circular shape of some of them; from their general form and arrangement; and from decisive indications of breaks, elevating the strata on the south side and sinking those on the north. The numerous dales that open into the valley of the Esk from the south, have originated in an equal number of fractures in the strata, aided by denudations, and in some instances there has been a compound fracture, the dale, which is single at its upper end, branching into two before it reaches the Esk, and enclosing between the two a hill, detached from the principal chain. This phenomenon, together with the steepness of the sides of this dale, and the soundness of their upper extremities must wholly set aside the idea that they could be followed out by the petty rivulets which meander through their rich alluvial bottoms."

There are then two ways in which valleys may be and have been formed—by breaks or fissures in the rocks and by the action of water.

At some past period, that part of the earth's surface which is now dry land was under the water, a fact proved by the character of rocks, and the fossils they contain. There was also a period when the great mountain chains did not exist,—they have been upheaved at different eras by a vast volcanic force. The elevation of these mountains, and even of the continents themselves, must have produced, in various places, fissures and chasms as well as valleys. Through these, large bodies of water have flowed, carrying away the loose fragments of rock, and by friction against the sides, smoothing, and as it were rounding the surface. A few observations on the two kinds of valleys, one called valleys of elevation, the other valleys of denudation, must be made before we pass on to another subject.

Valleys of elevation are those which have been occasioned by a fracture in the stratified rocks, and a simultaneous elevation of inferior masses. In Figure 6, Plate I., we have given a representation of a valley of this kind. The rocks at *a* and *b*, which are now separated from each other by an intervening rock, were once united, but by the elevation of that central mass, which in the order of deposition was below them, they

have been fissured, broken, and upheaved; the *highest portions of the strata at a and b forming the caps of hills or mountains. At that* part of the strata where the fissure was produced, and the ejected rock appeared, the bed was necessarily broken, and the fragments being swept away by streams of water, a comparatively smooth and, perhaps, now, fertile valley was formed. Elevation then is the agent by which the valley was produced, denudation that by which its form was modified.

There are a class of valleys, called valleys of denudation, in the formation of which water has been the sole agent. A valley of this kind is represented in Figure 1, Plate 2, where *a* may represent a bed of gravel, *b* a bed of sand; and *c* a bed of clay. No one could doubt, after the examination of a district in which there was an arrangement of rocks similar to that here described, of the former union of the beds now ranged on each side of the intervening valley. Undisturbed by any violent force, and having such a direction that the line of one would exactly unite with that of the other, we can find no agent capable of effecting the excavation, except water. Some persons have imagined that the rivers flowing in these valleys excavated

them; but not to say any thing of the fact, that some valleys have no rivers flowing through *them, it is quite certain such small and confined* streams are altogether inadequate to the effect. They have, in all probability, been scooped out by large moving masses of water, or, in other words, have been produced by floods; and such force must they have had, that nothing less than a sudden irruption of the sea can account for them.

THE DELUGE.

When we speak of the influence of large bodies of water upon the surface of the earth, the attention is at once drawn to that universal catastrophe which, in the early ages of the world, destroyed "both man and beast, and the creeping thing, and the fowls of the air." Geologists are by no means agreed as to the effect of the deluge upon the surface of the earth, but most are of opinion that to it may be attributed the formation of many valleys and the production and distribution of the gravel beds found in almost all countries. If such effects were produced by it, the present condition of many districts may be attributed to its action. But nothing can be more difficult than to assign to any

one revolution a particular class of effects, nor indeed can it be done with any certainty. From the account given of the catastrophe in the Jewish writings, and in the traditional records of all nations, it is certain that the great deluge, which covered the face of the earth and destroyed all living creatures, was occasioned by most violent and terrific agents, and those out of the common course of nature. The foundations of the great deep were broken up; by which may be understood that the bed of the sea was raised, or that fissures were opened, as sometimes happens during an earthquake in our own day, and from them streams of water were thrown. To fix any precise meaning to the phrase, we do not pretend; but by whatever means the effect was produced we know that the waters from above and those below mingled together, and so great was the flood that the summit of the highest hill was covered over; and it was not till "after the end of a hundred and fifty days the waters were abated." To estimate the effect of this deluge is impossible, but it is not presumptuous to state that the present form of the surface of the earth may be, in all probability, greatly attributed to it. The earth, in various places broken and fissured by

internal forces, must have been peculiarly exposed to the action of the waters, as they swept over the more elevated country, and retired to their beds. Valleys were scooped out, and the broken fragments of rocks were carried from country to country, by the momentum of the waters.

Philo, a celebrated and learned Jewish writer, speaks of the deluge in the following terms: "The vast ocean, being raised to an height which it had never before attained, rushed with a sudden inroad upon the islands and continents. The springs, rivers, and cataracts, confusedly mingling their streams, contributed to elevate the waters. Neither was the air quiet. Dense and continuous clouds covered the whole heavens; violent hurricanes, thunders, and lightnings, were blended with unintermitting torrents of rain; so that it seemed as if all parts of the universe were resolving themselves into the single element of water, until the fluid mass having at length accumulated from above and from below, not only the lower lands, but even the summits of the highest mountains were submerged, and disappeared. For every part of the earth sunk beneath the water, and the entire and perfect system of the world became muti-

lated, and deformed by a vast amputation." This was the opinion formed by Philo of the phenomena attending the deluge.

Let us now hear what Chrysostom, one of the most eloquent of the Greek Fathers, has to say on the subject. "Listen! the Deluge was the common wreck of the inhabited land; the cataracts were opened, the abyss flowed out again, and every thing was water; the visible things were resolved into their elements; earth no longer appeared, for all was sea.—Behold now a miracle! when the earth had been obliterated, when those who had worked wickedness were exterminated, and when the tempest had subsided, the summits of the mountains appeared; the ark rested; its doors were opened; and Noah went forth preserved from the wreck. He beheld the earth desolated, he beheld a tumultuary sepulchre, common to beasts and men; all the carcasses of horses and men, and of all unintelligent animals imbedded in the same tomb. He beheld that tragedy!—All had perished; neither man nor beast, nor any other of the things that were without the ark, was preserved; he beheld heaven only the same."

That the highest mountains of our globe have at some former period been covered by the sea,

cannot be for a moment doubted. "It is less extraordinary," says Mr. Greenough, "that water should have stood, at some former period, at a height exceeding that of our highest mountains, than that strata should have been formed without a precipitate, and that gravel should have been rounded without attrition." It is not to the deluge, however, that we must trace the deposit of shells and rocks on elevated plains and on the sides of mountains; they were produced beneath the surface of oceans and rivers, and were afterwards elevated by volcanic force; but we may attribute to it the scooping out of valleys, the formation of gravel, the transport of large bolders from one district and even one country to another, and, as some persons imagine, the production of limestone caves.

GEOLOGICAL PERIODS.

The young observer is at the commencement of his studies struck with the great duration of geological periods, and may at first doubt the accuracy of the deductions made by geologists. The position and situation of rocks are such that it is impossible to avoid the conclusion, to which all geologists have come, of an exceedingly

long duration between successive formations. This may be illustrated by an example; but to avoid the surprise with which the statement of periods of indefinite lengths may be met by one who hears of them for the first time, it is well to remember that all measurements, whether of time or dimensions, are relative. The dimensions of the earth when compared with things we are accustomed to witness and handle appear immense, but its circumference is as nothing when compared with the distance of the nearest fixed star, which, in its turn, vanishes when brought into comparison with more distant bodies, the very existence of which is only known by the use of the most powerful telescopes. That which is true in reference to distances is also evident in regard to duration. Man estimates periods by the ordinary length of human life. Threescore years and ten is to him a long existence, but this is not only insufficient for the formation of many of the mineral masses, but also, in the present day, too short to effect any visible change upon a district.

We were, however, about to adduce an example of the manner in which geological periods may be calculated, not by years, months, and days, as man is accustomed to estimate the lapse of time, but relatively—by a comparison of effects.

In Figure 2, Plate 2, is represented a series of rocks, in which three geological periods may be distinguished. Let the mass *a* be supposed a thick bed of clay, and *b* a gravelly bed; these two are distinguished as a formation, and they may be said to represent a geological period. Of the duration of the period some estimate may be formed by the character of the rocks, the fossils they contain, and the time required in the present day for the production of similar deposits. A bed of clay is the result of a quiet and uniform cause, and may be produced by sediment from the waters of an ocean, a lake, or a river. To determine in which a deposit has been formed, the organic remains must be examined, for no information can be derived from the mere inspection of the clay. If the remains of marine animals are found, the clay must have been deposited in salt water; if on the other hand the animals are known to exist only in lakes, the deposit is called lacustrine. But in whatever spot the bed may have been produced, a considerable time must have been required. Similar deposits are in the process of deposition in modern seas, rivers, and lakes; and from the slowness with which they are formed, we are led to the belief that many centuries would

be required to produce, under favourable circumstances, a bed of clay two or three hundred feet thick. The next and superposing *mass is one of gravel, for the* production of which more violent causes must have been in action. Pebbles contained in it are the result of moving bodies of water, for it is impossible to imagine them to have been rounded without attrition. Now we know by experiment and observation, that small angular fragments of rocks cannot be transported by a current with a velocity of less than three feet in a second. There must, therefore, have been a great change after the deposition of the clay; new and more violent agents were called into action, and their force was sufficient either to break away the fragments of solid rock, or to round by attrition those previously separated from the parent masses.

To imagine the character of a district during the formation of these two beds is not then difficult. A quiet sea and a slow action were the characteristics of the country when the sedimentary rock was forming, or a condition similar to that of many large bodies of water, in which analogous formations are going on. This must have been succeeded by violent floods, ac-

cumulating detritus, and probably acting on very extensive districts. The change may in this instance have been sudden, as when the calm and even course of natural agency is disturbed by a violent flood, as now sometimes happens in mountainous and tropical countries. Looking however at the probable course of physical events, it is impossible to escape the conclusion, that a lengthened period of time was required for the formation of these two beds.

Immediately after the cessation of the cause to which we have last referred, the central rock *c* may have been ejected, or a considerable interval may have transpired. The eruption itself was in all probability a sudden and almost momentary action, yet exerting an influence for a longer or shorter space after the agent itself had become quiescent. The violent eruptions of modern volcanoes are not of long duration, but volcanic mountains not unfrequently give evidence of their activity for a long period after the paroxysm has passed. The second period of which there is evidence in the sectional view of rocks may therefore have been comparatively short.

On the upturned edges of the disturbed strata two horizontal beds are lying, the lower

one *d* being a loose sand, and the upper a mass of chalk. Sand is the result of a quiet or at least continued aqueous cause. In the present day it is formed in the bed of rivers and in the basin of the ocean. The character of the deposits found in these situations must depend on the composition of the rocks in the immediate vicinity, or in those spots from which the current flows. Many rivers might be mentioned where clay is the sediment in one part and sand in another; the rocks and the currents accounting for the apparently singular variety. Some large sand-banks are in the process of formation in many parts of the ocean, and from what is known of them there is evidence in favour of the supposition which attributes the accumulation to a slow and long continued action of water upon silicious rocks. Chalk and other calcareous rocks are attributed to springs and to the disintegrated fragments of shells, and must therefore require a long duration for their production, when of great thickness, as in the chalk, which is sometimes several hundred feet deep.

In this brief account of a particular series of rocks, no allusion has been made to an alteration in the character of the organic re-

mains. The existence of shells belonging to animals who inhabited rivers and lakes, and of others who dwelt in the ocean, has been mentioned, and the reader must perceive the importance of this fact in every attempt to ascertain the comparative length of a geological period. If of three beds in contact, the highest and lowest should be marine, and the central terrestrial or lacustrine, the geologist has not only to estimate the period required for the production of the several deposits, but also the time that would elapse before the bed of the ocean could be converted into an inland lake, and that again united with the sea. Such effects may, it is true, be rapidly produced; but they are usually the work of ages. In the former case evidence of the violent action would be found in the existence of gravel or some similar mass.

From these observations, then, it will appear, that different rocks resulted from an alteration in the prevailing agency, and that such changes cannot always be occasioned by a sudden revolution. But the crust of our earth consists of thousands of beds of various mineralogical characters, and containing a vast variety of organic remains. The animals to which they belonged

must have lived, died, and been entombed in the beds formed during the existence of that state of inanimate nature suited to their peculiarities of character. To change the inhabitants of a district or country, a gradual agency must be called into activity, for no one will imagine that a new and distinct race of creatures was in a moment brought into existence to inhabit the spot before crowded with beings having an altogether distinct physical character.

These general remarks will, it is hoped, put the reader in possession of the most important elementary principles of the science of geology. Having explained the arrangement of rocks, the revolutions to which they have been subject, and the deductions drawn from these circumstances, we may now enter with more particularity into an account of the manner in which they are classified, the peculiarities by which they are known, and the organic remains they contain.

CHAPTER II.

THE CLASSIFICATION OF ROCKS.

It has always been thought necessary, for the prosecution of scientific research, to establish, as early as possible, a classification of the objects to be studied. In every branch of natural history this has been done, and the early efforts to arrange and, as it were, systematize the varieties, have been, in many respects useful, and in others extremely detrimental to the progress of science. Systems generally, and particularly those formed at the commencement of a study, are established on some theoretical opinion, which, whether true or false, must have its supporters and its opponents; the one attempting to sustain the system for the theory's sake, and the other rejecting the classification from a dislike to the hypothesis. In this manner a party spirit is engendered among the fol-

lowers of science, strife follows, and truth is neglected or forgotten in the attempt to establish a particular class of opinions. It was thus when geology was first introduced as a science to the notice of philosophic minds: it was less studied from the singularity and importance of the facts it developed than as a means by which the ambitious and ingenious might signalize themselves by embarking their adventurous talents on the sea of controversy.

The division of rocks first adopted by geologists consisted of two classes, the primitive and the secondary. A more minute examination of mineral masses, however, convinced observers that there were, between the two classes, certain rocks which had external characters, and probably an origin different from both, and these were united into a third class, called the transition. Modern authors have adopted a fourth order, including the rocks lying above the chalk, and this is called the tertiary class. A brief account of all these may be given before we proceed to speak of the superposition of rocks, and their union in formations.

The primitive or primary class includes all those crystalline rocks forming the base of the entire series. The term was derived from a

supposition that they formed a part of the earth as it came from the hand of the Creator, or at least were produced before the existence of vegetable and animal life. The rocks belonging to this class are granite, gneiss, porphyry, and others, and from an examination of them it must now be quite evident that they for the most part are ancient igneous masses, though it is not universally allowed that they were all produced in the same manner as the lavas of the present day. We have spoken of these rocks as being the lowest of that series with which we are acquainted—those on which all others rest; but they sometimes form the summit of the highest mountains, and are in fact the most lofty points of the globe. The action of subterranean forces has upheaved them, and by their elevation the sedimentary rocks were disturbed.

We must not pass over this subject without alluding to the nebular hypothesis which has recently been applied to account for the formation of the earth. It is not necessary that any opinion should be risked, or rather intruded, for the phenomena on which the theory is founded are still but imperfectly known, and nothing more can be necessary than a brief statement of

the observations which have been made, and of the violent or at least hasty deductions drawn from them.

There are in various parts of the heavens certain nebulous formations in different stages of condensation, and by a comparison of them it has been supposed that the matter first existing in a diffused state is gradually condensed until a hard, compact, and spheroidal body is at last formed—a perfect world suited to the support of vegetable and animal life. It may be readily admitted, that from the apparently successive and gradual alteration of character in nebulous matter, there is a strong probability that a mere luminous nebulosity may, after a certain period, be condensed, and ultimately assume an apparent density of form. An astronomer, who examines the heavens and finds a great variety of bodies in different stages of condensation, has as much confidence in combining his observations into a system and asserting that one stage leads to another, as a botanist has in selecting from a forest a series of plants and stating that the delicate shrub will, at some future time, produce the stately and full grown tree; but it must be remembered that as a botanist who examines for the first time a forest

containing different species of trees may fail in tracing the tender plant to its full growth, and even confuse one tree with another, from one false step; so an astronomer, after examining all the most remarkable nebulæ, may fail in some steps of his generalization, and come to conclusions far, very far, from the truth. It has, however, upon the uncertain evidence of a few astronomical observations, been confidently stated that the earth is the product of nebulosity; and that it is a cast-off fragment from a condensed nebulous centre. The difficulties which now stand in the way of the adoption of this hypothesis are great, and we may state them by questions; but it will be sufficient to propose the following:—

If the solar system be the result of nebulosity, how did it happen that the large fragments now formed into planets were thrown from the central accumulation? What can account for the self-illuminated properties of the sun? What is the cause of the almost infinite varieties of the mineral masses? And to what cause can be attributed the existence and numberless variety of vegetable and animal life? To these queries many others might be added, but we

will leave the subject without farther notice, and proceed to consider the nature and production of the transition rocks.

The transition rocks rest on the primitives, and are more or less distinctly stratified; in them organic remains are first found. From these two circumstances, and from their general appearance, it may be supposed that they were produced by sediment, and have since been extensively acted on by heat. They are sometimes called the fragmentary rocks, under the supposition that they are the accumulations of the detritus of the primitive masses. The general opinion was, and is still entertained by most persons, that the transition rocks were produced at the period when the earth first became capable of supporting life. The organic remains are shells, corals, and plants.

The secondary rocks are very numerous, and have been formed by sediment or deposition upon the transition. Coal and its associated beds form the lowest group, and the cretaceous, including the green sands and chalk, the highest. In nearly all these are found the remains of plants, zoophytes, shells, fishes, or reptiles. The beds were, when first deposited, horizontal, but by successive upheavings, have been tilted

and disturbed, more or less, so that they may be seen at almost every angle of inclination. "A great majority of the strata," says the eloquent author of Vindiciæ Geologicæ, "having been formed under water, and from materials evidently in such a state as to subject their arrangement to the laws of gravitation, had no disturbing forces interposed, they must have formed layers almost regularly horizontal, and therefore investing in concentric coats the nucleus of the earth. But the actual position of these beds is, generally more or less inclined to the horizontal plane, though often under an angle almost imperceptible. By this arrangement, many strata affording numerous varieties of mineral productions are made to emerge in succession on the surface of the earth; whereas the inferior must have been buried for ever beneath the highest had their position been horizontal." It cannot be supposed that the same bed would have extended over the entire surface of the earth, but the same or a similar series of beds, according to circumstances, as now form the crust, would have been so united, as to produce a continuous covering, hiding from view all the inferior rocks.

The stratified rocks have evidently been formed

from the destruction of others, and from the activity of chemical agents. The extent of these beds has of course been regulated by the extent of the agent by which they were produced. It is almost impossible to imagine a constant and equal supply of detritus over the entire bed of an ocean, and still less the equal deposition in all places. In modern seas deposits are formed, but they are local, and produce shoals and banks; parts of the German and other oceans are thus encumbered. It is easy then to perceive, from an acquaintance with the circumstances under which rocks are now being formed, that although a geological period may be distinguished by a particular condition of physical agents, yet the same deposit cannot be continuous over a very large surface; and beds differing from the principal ones in every respect may be found, and prove the existence of local causes more or less violent than that by which the formation was produced. A rock which is the most important member of a formation in one place may be absent from the same formation in another place, or may be represented by a deposit having an altogether different mineralogical character—a clay in one country, a limestone in another.

"The lowest and most level lands," says Cuvier, "when penetrated to a very great depth, exhibit nothing but horizontal strata, consisting of various substances, almost all of them containing innumerable productions of the sea. Similar strata, similar productions compose the hills, even to a great height. Sometimes the shells are so numerous, that they form of themselves the entire mass of the stratum. They are almost every where so completely preserved, that even the smallest of them retain their most delicate parts, their most slender processes, and their finest points. They are found in elevations above the level of every part of the ocean, and in places to which the sea could not now be conveyed by any existing causes. They are not only enveloped in loose sands, but are incrusted by the hardest stones, which they penetrate in all directions. Every part of the world, both the hemispheres, all continents, all islands, of any considerable extent, exhibit the same phenomenon." "They (the fish whose remains are found) have therefore," he says in another place, "lived in the sea, and have been deposited by the sea; the sea must therefore have existed in the places where it has left them." "We are then led," he says again, "to believe

not only that the sea has occupied all our plains but that it must have remained stationary there for a long time, in order to have been able to form deposits so extensive, so thick, in part so solid, and containing exuviæ so perfectly preserved: the basin of the sea has therefore undergone one change at least, either in extent or in situation. Such is the immediate result of the first examination, and of the most superficial observations."

These are the deductions drawn from the existence of fossils in stratified deposits; for it is by them we are taught the circumstances under which the rocks that entomb them were produced, and discover that one was deposited in the sea, and another in fresh water. Nothing can impress the mind more strongly with the extended duration of geological periods, and the immense period of time required in the deposition of the secondary rocks, than the alternation of marine and freshwater beds. Not only have the various changes in the ancient sea increased the depth of the sediments and caused, in some places, the appearance of shoals at the surface of the water, but districts and counties which had been laid dry, and were inhabited by terrestrial animals, and lakes and rivers containing

freshwater fish, have been covered with salt water, either by the sinking of the land or the elevation of the sea. After a lengthened period, sufficiently so at least to admit the deposition of beds or strata crowded with the remains of marine animals, the water has again been thrown off, and the district has become the habitation of quadrupeds and birds, and clothed with terrestrial plants.

By extraneous fossils alone, says a French naturalist, we are able to ascertain, with the utmost certainty, that our earth has not always been covered with the same external crust; because we are positively assured, that the organic bodies to which those fossil remains belong must have lived upon the surface, before they came to be buried, as they now are, at a great depth. In regard to quadrupeds, every thing is precise. The appearance of their bones in strata, and still more of their entire carcasses, clearly establishes, that the bed in which they are found must have been previously laid dry. Their disappearance as clearly announces that this stratum must have been inundated, or that the dry land had ceased to exist in that state. It is from them, therefore, that we learn with perfect certainty the important fact, of the

repeated irruptions of the sea upon the land, which fact fossils of marine origin could not have proved; and by a careful examination of them, we may hope to ascertain the numbers and epochas of those irruptions of the sea.

These general remarks on the condition of the secondary rocks, their fossils, and the deductions drawn from their appearance, are introduced to prevent the necessity of a constant reference to elementary principles in the short description we shall presently give of them.

The tertiary rocks lie above the secondary, and have been deposited in the hollows of the chalk and other formations. They contain the remains of plants, fishes, and mammalia, the latter being found in no other beds, with one exception.

Diluvium is a general term for all those accumulations of water-worn materials broken from ancient rocks, and containing the remains of extinct and recent animals. These beds have been produced by a violent diluvian action; the rushing of bodies of water over the surface of the earth, which have not only broken large fragments from ancient rocks and the fossils they contain, but have destroyed the animals

then living on the surface, and provided for all the same tomb.

The alluvium beds are those due to existing causes;—such as, deposits from seas, rivers, and springs; and in fact, all those accumulations of mineral matter now forming on the surface of the earth, including the lavas ejected by volcanoes.

Such was the classification almost universally adopted in this country prior to the publication of Mr. Conybeare's Geology of England and Wales, in which a new arrangement was adopted, so as to separate the terms from the admittance of any theory. This was a great improvement but was never fully adopted, either in conversation or in writing; for geologists continued to speak of the primary and secondary rocks as they do to this day. Nothing is more difficult than to change the nomenclature of a science, and the attempt must never be made without consideration, for it is a fruitful source of confusion; beside which there is always an attachment to terms familiarized to us as a native language from the commencement of study and during the progressive development of our opinions. Still all geologists were agreed in deprecating the old

classification, so that it is singular the improvement was not immediately adopted and introduced in elementary works and scientific memoirs. Another arrangement of rocks has been proposed by M. De la Beche, which is, in our opinion, by far the most convenient and natural yet brought before the notice of scientific men. In the following table we have adopted the system of dividing the aqueous rocks into groups, and shall follow it throughout the work.

Rocks may, in the first place, be divided into two natural orders, the stratified and the unstratified. The stratified rocks may be subdivided into two classes, the fossiliferous and the non-fossiliferous, and as the latter occupy the lowest place in the series, no confusion can arise from this arrangement. The superior stratified or fossiliferous rocks may be divided into nine classes, which, proceeding from the summit downward, are as follows:—

1. Modern group.—2. Erratic block group.—3. Super-Cretaceous group.—4. Cretaceous group.—5. Oolitic group.—6. Red sandstone group.—7. Carboniferous group.—8. Grauwacke group.—9. Lower fossiliferous group.

In the succeeding table the several formations are placed in the groups to which they belong.

CLASSIFICATION OF FOSSILIFEROUS ROCKS.

1. *Modern Group.*—Deposits in seas, rivers, and lakes; rocks formed by corals and springs; accumulations of detritus by atmospheric causes: lavas thrown from active volcanoes; and all other mineral deposits produced by causes having a present activity.

2. *Erratic Block Group.*—Gravel, transported boulders, and all rocks not belonging to the previous class, formed by the action of sudden and violent floods, and containing ancient and modern organic remains intermixed.

3. *Super-Cretaceous Group.*—Deposits above the chalk. Many of these are so isolated that their order cannot be determined: the following however may be mentioned;—the crag, upper freshwater, upper marine, and second or gypseous fresh-water formations, London clay or calcaire grossier, and the plastic clay.

4. *Cretaceous Group.*—Chalk, upper green sand, gault, lower green sand, and the wealden formation, which includes the weald clay, Hastings sands, and Purbeck limestone.

5. *Oolitic group.*—Portland oolite, Kimmeride clay, coral rag, Oxford clay, cornbrash,

forest marble, Bradford clay, great oolite, fuller's earth, inferior oolite, lias.

6. *Red Sandstone Group.* — Variegated or red marle, muschelkalk, new red sandstone, zechstein, red conglomerate.

7. *Carboniferous Group.* — Coal measures, millstone grit and shale, carboniferous limestone.

8. *Grauwacke Group.* — Old red sandstone, thick bedded and schistose grauwache, grauwache limestones, grauwacke slates.

9. *Lower Fossiliferous Group.*—Slates of various kinds frequently connected with stratified rocks, or resembling some found among the unstratified class.

The inferior stratified or non-fossiliferous class consists of various stratified rocks of a schistose character.

The unstratified rocks are of two classes, ancient and modern, but the modern lavas may with great propriety, for the purpose of instruction, be considered with the modern sedimentary rocks. The ancient unstratified rocks are basalt, trachyte, greenstone, porphyry, hornblende, augite, serpentine, diallage rock, sienite, and granite.

Another classification of rocks has been more

recently adopted by some geologists. This arrangement however is founded on theoretical opinions, a circumstance which should always be borne in mind by those who employ it in teaching the science of geology. Rocks, when considered in reference to their probable origin, may be divided into four classes, which, severally include the aqueous, volcanic, plutonic, and metamorphic masses.

Under the general term aqueous rocks are included all those which have been formed by the agency of water. The greater number of these have been produced by a gradual accumulation of detritus, and contain the remains of organized beings, which enable us to determine whether the bed, or formation, was deposited in fresh or salt water.

Volcanic rocks are those which were produced by fire, and may be divided into two classes, ancient and modern, or, as some authors have professed to arrange them, post and ante-diluvial. As aqueous rocks are in the process of formation by water, so volcanic rocks are constantly produced by subterranean heat, and the characters of the one and the other are so strongly marked it is impossible to mistake them. When the basaltic rocks generally are compared with the

modern lavas, there can be no doubt that they have a similarity of origin, that they were ejected from the interior of the earth in an intumescent state, whether they appear as overlying or columnar masses; or filling fissures, by intrusion from above, and ejection from below. That we find no ancient volcanic cones is a matter of small moment, for supposing that the ancient volcanic rocks were ejected from cones, such has been the violence of the geological changes that their existence could not be now expected. But a slight reflection on the origin of these cones will remove the difficulty from the mind of the least experienced observer, for they are not produced by a single eruption, but by a series of paroxysms, each of which are, in some instances, separated by periods of nearly a century.

The third class of rocks, called the plutonic, is one of mere convenience, and includes the granites and some porphyries. It is admitted by all persons that although the granites were evidently formed by the action of intense heat and have many characters, such as their existence in veins and dikes, in common with the volcanic rocks; yet in their crystalline structure and the absence of tuffs and breccias they are

essentially distinct. At the same time it must be remembered that the granites are not unfrequently known to pass from one state to another until they are identified in character with the volcanic rocks. This fact, in connection with the not less important one, that they are seldom found as overlying masses, has induced the opinion that they were produced by heat, under immense pressure. The reader may fancy the operation by supposing the heat producing volcanic action to be centralized. The rocks surrounding a focus of heat would be equally affected, supposing the conduction to be the same in every direction; those lying above would be melted, and the gases given off, exerting an expansive force, would rend the solid though heated overlying beds, and the intumescent mass would rise in the fissure and in all probability overflow the surface. Being in a liquified state, and cooling in the atmosphere, it would, as we well know by experiment, assume the vitreous and frequent cellular character by which lavas are distinguished. The mineral masses which lie beneath the point in which the calorific power may be supposed to be centralized are also brought into a state of more or less perfect fusion, but they are at the same time exposed to

a considerable external pressure, and during the slow process of cooling assume a crystallized structure.

The fourth class of rocks, which includes gneiss, mica, clay and chlorite slates, primitive marble, and associated rocks of the same character, is called metamorphic. These rocks are stratified, and frequently have a crystalline structure. They have been called metamorphic from the supposition that their external characters have been transformed. It is supposed that they were originally deposited by water, but, being subsequently acted upon by subterranean heat, assumed the characters which now distinguish them.

If this view of the origin of rocks be true, it will necessarily follow that rocks of all the several classes may have been formed contemporaneously. The volcanic rocks we find intermixed with aqueous deposits of all ages, and by this union we are able to determine the relative periods of their formation. But during the eruption of volcanic rocks, the plutonic and metamorphic must have been produced. An extensive field of investigation is here opened to the practical Geologist.

This general view of the classification of rocks

will assist the reader in forming some conception of the extent of Geology, and also prepare him for the investigations into which we are about to enter. In attempting to explain some of the most remarkable facts of the science of Geology, we shall find it of advantage to trace the origin of a few modern sedimentary rocks, and the influence of volcanoes and earthquakes. The different classes of rocks will then come under our consideration. In describing the aqueous rocks we shall adopt the classification proposed by M. De la Beche; and commence with that group which lies on the top of the series, and describe the several deposits in an order the reverse of that in which they were formed. To some persons this may appear an improper method of teaching the science, but when it is remembered that all our knowledge concerning the formation of rocks must be derived from phenomena attending the activity of existing agents, it will be evident that the most certain method of studying the origin of ancient rocks is to ascertain the manner in which mineral masses are now formed.

CHAPTER III.

THE ORIGIN OF MODERN SEDIMENTARY ROCKS.

The term rock is, by the geologist, applied to all mineral masses, so that sand and clay come under the designation. At the head of this chapter we have used the word in the same sense, and wish to comprehend not only the masses elevated above the fluids by which they were deposited, but also those in the process of formation in the beds of oceans, lakes, and rivers.

Mutability is the characteristic of all terrestrial conditions—nothing is constant, and durability is an attribute which has no positive existence. The hardest rock is crumbling under the influence of the softest breezes of heaven, and the loftiest peaks are stooping under the power of the frost by which they are clothed. There is no physical condition that can be called

certain—that which was yesterday is not to day —the destruction and recomposition of rocks is constantly going on, and the stability of the new accumulations can scarcely outlive their formation. To trace the agents of destruction and recombination is now our object, not merely for the purpose of obtaining some information of present causes, but also to ascertain the nature of those that produced the ancient rocks.

The changes undergone by the surface of the earth are chiefly to be attributed to the action of water. Atmospheric agents, though apparently weak and insufficient, have an influence, and by moderate as well as violent means crumble the hardest and most enduring mineral masses. Water may act both chemically and mechanically upon rocks. It acts mechanically when in passing over the surface it removes a portion of the soil, separates projecting masses, and undermines cliffs. But in all these cases the amount of the destructive influence is greatly aided when the moving water contains solid particles, derived from its previous action; as, for instance, always happens in rivers as they approach the sea or basin where they discharge their waters. In the first part of their course the power of abrasion is attributable to the water alone, but as they flow

onward they collect adventitious matter which aids them in their subsequent destroying agency. The effects produced in mountainous countries by the consolidation of water, and the motion of glaciers, may also be classed among the mechanical destroying agencies of water. It acts chemically when a decomposition of the substance is effected.

DESTROYING EFFECTS OF RIVERS.

The small streams of water resulting from springs, or the melting of ice and snow in mountainous countries, are called rivulets. As these flow from the high to the lower districts they are joined by other streams, and, increasing in size and momentum, are called rivers. It will be at once understood that the existence of a river presupposes an inequality in the elevation of the country, for there could be no progressive motion of a body of water on a perfectly level plain. The velocity of a river does in part, but not altogether, depend on the declivity. The bed of the Rhine, for instance, is much more inclined than that of the Danube, but it is much less rapid; and the Inn, which forms the southern branch of the Danube, is so much more rapid than that river, it actually rushes across

the Danube at Passau. There must, then, be some other circumstance than that of inclination to account for velocity, and it is the volume of water. A river is always most rapid where the channel is deep and narrow, and the volume of water great.

The strength of a river, or in other words, its destroying effect upon its own channel, depends on the volume of water, and the velocity with which it moves. The rivers of our own country, winding slowly through fertile districts, might afford us some evidence of the action of running water. The banks are constantly worn and even undermined by the current, and the broken fragments are swept along in its course; large deposits also are formed of these rocks choking up the channel, and giving either an increased velocity to the stream, or compelling it to cut for itself a new channel; but we must look to other countries if we would form an accurate estimate of the abrading power of rivers. Many have cut their own channels in hard rocks, of which the Elbe, near Pirna, and the Hudson, in America, are examples. It is not to be supposed that a river can open for itself a passage through a solid rock, but directed by natural declivities it can wear away the mineral mass, and form for itself a convenient channel.

The transporting power of running water is much greater than might be expected. Not only are small fragments and gravel carried by them to the seas into which they flow, but also immense blocks. It must, however, be remembered, that their specific gravity is less in water than in air; or, in other words, they are bulk for bulk lighter. This is a fact easily explained, and must have been observed by the reader; for a stone which could scarcely be lifted in the air may be raised with comparative ease in water; and every one knows that a bucket of water when raised in a well increases greatly in weight as soon as it leaves the water.

The Nile offers us one illustration of the power of running water to destroy rocks. This celebrated river is known to annually overflow its banks, and is at that time so charged with earthy matter, as during a few days to deposit a rich soil upon the plains it inundates. The great celebrity of the Nile may be traced to the importance of the country through which it flows (a country in which the arts and sciences were nursed), and to the ignorance of the ancients as to the origin of the inundation. Modern geographers are aware that every river which has its scource within the tropics annually overflows its

banks, a phenomenon once attributed to the Nile only. The cause also is known to be the torrents of rain always falling during the winter season, and the rushing of streams from the mountains into the valleys. These streams in their rapid progress collect a large quantity of mineral matter, and, carrying it with them into the rivers, give an increased destroying force from the detritus, as well as the volume of water. The innudation of the Nile commences generally about the nineteenth of June, and subsides in October.

The Amazon or Maranon, a mighty river in South America, flowing over an immense district, and said to be more than three thousand British miles in length from its source to its mouth, would also afford us other examples of the destroying power of running water. Of this mighty river it may be said —

> Scarce the muse
> Dare stretch her wing o'er this enormous mass
> Of rushing waters; to whose dread expanse,
> Continuous depth, and wondrous length of course,
> Our rivers are but rills.

Between Cape North and Punta el Baxos, the Amazon, by numerous mouths, enters the sea, and with such violence, that it forces itself

through the waves of the ocean, and pursues its course unmixed for a distance of forty leagues. The influence of such a vast body of water rushing forward with tremendous force is past calculation. We may, however, turn from this to another large American river, the Mississippi, well known to be encumbered with the sand and other detritus formed by its own waters.

"The Mississippi," says Volney, "strong in a body of yellowish muddy water two or three thousand yards broad, which it annually rolls to the height of twenty-five feet over its banks, urges this immense mass of sand and clay; forms islands and destroys them; floats along trees, which it afterwards overturns; varies its course through the obstructions it creates for itself, and at length reaches you at a distance where you would have supposed yourself perfectly safe." These masses of sand rolling onward form constantly shifting bars, impeding the navigation, and with the accumulations of timber, absolutely choking its course. The inundations commence in the month May, and attain a great height; and so loaded is it with detritus, that half a pint of water in a tumbler will deposit a sediment two inches in thickness.

Many other examples of the action of rivers

upon the countries through which they flow, in destroying rocks, might be mentioned; these however are sufficient to establish the truth of the statement we have made, if any were required beyond those which must have come under the notice of the reader, wherever he may have been residing. But what must be the effect when a large body of water is pent up and suddenly let loose through a channel too small to convey it? Many instances of this have occurred at various times, and we cannot convey a more accurate impression of the vast influence of the destroying agent, than by a description of the inundations of the Val de Bagnes.

DESTROYING EFFECTS OF FLOODS.

The Val de Bagnes, a valley in Switzerland, is about ten leagues in length, and is watered by the river Dranse, "which flows in a rocky bed, contracting its channel between precipitous banks, where it cuts the mountainous ridges, and again spreading out upon level and fertile plains covered with smiling cottages, and presenting the most picturesque and beautiful situations." The Dranse has its origin in the glaciers of Tzermotane and Mont Durant. After flowing through

a valley, the waters enter a narrow and deep channel, over which is built the bridge of Mauvoisin. "This bridge is built upon perpendicular rocks, about eighty feet above the bed of the river; and the narrow gorge which it crosses, is formed by the approximating flanks of Mont Pleureur on one side and Mont Mauvoisin on the other. Between Mont Pleureur and Mont Getroz is a narrow and deep channel, at the top of which lies the glacier of Getroz." From this glacier enormous masses of ice are often thrown into the ravine below, and when carried to the bottom of the valley fill up the channel of the Dranse. The waters are thus accumulated until they are many feet above the level of the surrounding country. After perhaps many days, or even weeks, the ice is melted, or the barrier gives way, and the confined water rushes with tremendous fury over the low lands, until its force is expended by the obstacles with which it meets.

An accident of this sort occurred in 1545, when the village of Bagnes was destroyed, and a hundred and forty persons were killed. In 1595 the valley above the bridge of Mauvoisin was closed by ice, and the confined water continued to rise in height until the barrier,

weakened by a thaw, gave way. With irresistible fury the water rushed into the plains, carrying before it every thing that resisted its progress, transporting enormous masses of rock, tearing up trees, and in fact desolating the plains and destroying the whole town of Martigny, with from sixty to eighty of the inhabitants. It is to a later accident of the same kind we are about to refer.

For several years previous to 1818, the water of the Dranse had been in some degree obstructed by the ice and snow falling from the glacier of Getroz. Gradually increasing in size it at last became a large conical hill, its summit being full one hundred feet above the Dranse. Until the month of April the water found a passage through the base of the cone, but the opening was then closed, and a lake half a league in length was produced. The inhabitants of the surrounding country then entertained a great fear that the water would soon force a passage, and that immense damage might be produced by its rushing through the valley. It was therefore proposed to construct a subterranean gallery so as to effect a gradual discharge. "With this view, the lower end of the gallery was made sixty feet below that part where the

cone of ice was in contact with the flank of Mont Mauvoisin, and its upper extremity was fixed at the height to which the lake might be calculated to have risen when the gallery was finished. In this way, the water, entering the upper extremity of the gallery, might be expected to deepen it by degrees, and thus permit the surface of the lake to descend gradually, till it was nearly emptied. This ingenious and bold scheme was begun on the 10th of May, and finished on the 13th of June, under the direction of M. Venetz, an able engineer. The gallery was sixty-eight feet long, and, during the formation, the workmen were exposed to the constant risk of being crushed to pieces by the falling blocks of ice, or of being buried under the glacier itself.

"During the thirty-four days spent in the formation of the gallery the lake had risen sixty-two feet, but from particular causes, the upper entrance to the gallery was still many feet above the surface of the lake. Without waiting for the farther rise of the waters, M. Venetz sunk the floor of the gallery several feet, and the water began to enter it on the 13th of June. At this period, the length of the lake was from 10,000 to 12,000 feet; its average breadth, at the surface, about 700 feet, and, at the bottom,

about 100 feet. Its absolute average breadth was 400 feet; its average depth 200 feet; and its contents at least 800 millions of cubic feet.

"After the 14th of June, at eleven o'clock, the floor of the gallery began to wear down, and at five o'clock the lake was lowered one foot. On the 15th of June, at six o'clock in the morning, the height of the lake was diminished ten feet; twenty-four hours afterwards, it was diminished thirty-six feet; and on the 16th of June, at six o'clock in the evening, the total diminution was forty five feet. The effect of the gallery, therefore, had been to reduce the lake from 800 to 530 millions of cubit feet."

From this account it will be easy to perceive that the gallery was worn away by the velocity of the water, which also penetrated the crevices of the glacier, and caused enormous masses of ice to fall. In a day or two the thickness of the floor of the gallery was reduced from six hundred to eight feet. At last the water excavated for itself a passage between the glacier and the foot of Mont Mauvoisin. The ice then gave way, the water rushed out, and in half an hour the lake was emptied. It may be readily imagined that such an enormous body of water suddenly freed from restraint and rushing

over a country would sweep before it every thing that could in the slightest degree impede its progress, and the amount of injury cannot be calculated. No resistance was offered to the raging flood until it came into the narrow gorge between Mont Pleureur and a projecting part of Mont Mauvoisin; and here it was so engulfed that the bridge of Mauvoisin, ninety feet above the Dranse, was carried away. The channel being thus contracted, in several parts of the valley, the force was increased, and the flood carried with it forests, rocks, houses, and even the cultivated land; so that when it reached the village of Le Chable it seemed to consist more of stones, earth, and other solids, collected in its progress, than of water. At this part of the valley the flood was pent up between the piers of a solid bridge nearly sixty feet above the Dranse, and began to attack the inclined plane upon which the church and chief part of the village is built. An additional rise of a few feet would have instantly undermined the village, but at this critical moment the bridge gave way, and carried with it the houses at its two extremities. The flood now spread itself over the wide part of the valley between Le Chable and St. Branchier, undermining, destroying, and sweeping

away the houses, the roads, the richest crops, and the finest trees loaded with fruit. Instead of being encumbered with these spoils, the moving chaos received from them new force; and when it entered the narrow valley from St. Branchier to Martigny, it continued its work of destruction till its fury became weakened by expanding itself over the great plain formed by the valley of the Rhone. After ravaging Le Bourg, and the village of Martigny, it fell with comparative tranquillity into the Rhone, leaving behind it on the plains of Martigny the wreck of houses, and of furniture, thousands of trees torn up by the roots, and the bodies of men and of animals whom it had swept away."

To this account we might add many other examples of the tremendous power of floods, but our object is to give a general view, and the reader himself will be able to find abundant examples. The effect of these catastrophes, from whatever cause they may arise, must be that of producing an immense change in the districts over which the waters flow, not only by sweeping away the loose substances in its path, but by throwing down fragments of hard rocks, and scooping out valleys. The diluvian beds, of which we shall presently have occasion to

speak, were probably produced in a similar manner.

DESTROYING EFFECTS OF THE SEA.

The destroying effect of the ocean upon its coasts is very great. When it is bounded and restrained by bold and rugged cliffs, it is almost constantly throwing its waves with violence against them, so that they are crumbled, split, or thrown down, the effect varying with the nature of the rock. If we turn to the rocky shores of the north, we find them undermined by the action of the waves, and perforated in every direction. When a strong current sets in upon a projecting headland, it is, in the course of time, worn through and separated from the shore. In the Shetland isles, and off the coasts of Norway and Scotland, there are many interesting examples. Caves also may be formed and modified by the action of the waves upon the coast. When the cliff is composed of more yielding materials, the destruction is of course greater; an example may be found in the isle of Sheppey. The cliffs on that island are, from east to west, about six miles in length, gradually declining at each end. The more elevated parts are about 100 feet in height, and they are

throughout composed of clay. Every tide their base is washed by the waves, which beat against them with much force when driven by easterly winds. In this way the lower part of the cliff is scooped out, and the upper portion being unsupported falls on the beach. For a short time the detritus thus accumulated protects the coast from farther ravages, but in a few tides the clay is removed, and the action is recommenced. Many acres of land are in this manner annually thrown down, and the boundary of the sea extended: it has been computed by some writers that the island is not now more than one half the size it was fifty years ago: whether this calculation is founded upon an accurate examination, or from conjecture; we cannot say, but of the rapid inroad of the ocean there cannot be the slightest doubt. The destruction of the cliffs, however, is aided by atmospheric causes and land springs. The clay contains a very large quantity of the sulphate of iron, with which all the fossils are impregnated. Streams of water containing the same mineral are seen flowing from the perpendicular cliffs, and these bring with them portions of the earth, loosen the mass, and render it less able to resist external agents. Rain beating upon them, and the

certain actions of frost, connected with alternate moisture and rapid drying in hot weather, unite their influence. That which is going on in this one spot is also effected in some degree at all those places where cliffs of clay are exposed to the waves of the ocean.

Mr. Bell has collected several instances of the action of the sea upon low lands, the inroads of which are of a most fearful character. "The Zuyder sea was formerly a small inland lake, formed by an arm of the Rhine; but in the thirteenth century the sea covered a large part of the surrounding continent, and formed this basin. In 1421 the sea swallowed, in one night, seventy-two villages, with a hundred thousand inhabitants, in the neighbourhood of Dordrecht, and changed the whole surrounding country into a lake. In the same manner the Dollart, near East Friesland, was formed, in the thirteenth century, by the sea overflowing a well cultivated tract of land. Much of the western coast of Sleswick has been swallowed by the sea. The island of Norstrand was buried, in 1634, almost entirely by the waters; and of Heligoland nothing remains but the rocks. Many more events like these may have happened in ancient times, which are not recorded in history. Several

straits bear certain traces of the sea having broken through them; and many groups of islands have evidently been torn from one another by the action of the waves. Between Calais and Dovor an isthmus probably existed in former times, which has been broken through by the waters; for the soil rises on both sides, forming a kind of dyke, exhibiting corresponding strata; and the ridge of mountains which in France terminates at Calais rises at the point of land in Kent, in the same direction, and contains the same minerals, according to Desmarets. The three straits which lead from the ocean into the Baltic have probably been formed by the breaking through of the sea, as the name seems to show; for the old national word *belt* still signifies, in Friesland, an inroad of the sea. It was believed by the ancients, that Sicily had in former times been connected with Calabria, but was afterwards severed from it by the waves. According to an old tradition, which seems to be confirmed by the existence of the rock called Adam's Bridge, Ceylon was formerly connected with Coromandel; and there is no probability that the straits of the Dardanelles, of Constantinople, and of Gibraltar, originally existed in their present state. Most

likely America, too, was connected formerly with Asia, by a natural bridge, over which the first inhabitants came, and which was afterwards destroyed by the waves. The indented outline of almost all coasts, and the situation of most islands, bear distinct marks of violent disruption by the action of water."

In speaking of the action of the sea upon rocks, it must not be forgotten, that its power is exercised over them beneath its surface, as well as upon the cliffs and low lands which bound it. According to Mr. Stevenson, the ocean is agitated to a depth of two hundred feet below the surface, and that it has there sufficient power to break rocks in pieces, and throw the fragments towards the shores. Drift stones, measuring upwards of thirty cubic feet, and more than two tons in weight have been thrown on the Bell Rock, where the celebrated light-house is built, during storms, and from the depths of the ocean. These boulder stones are called travellers by the light-house keepers.

DESTRUCTION OF ROCKS FROM SLIPS.

Water acts in another and still more singular manner in the destruction of rocks by percolation. We do not here refer to the carrying away of

earthy particles in streams, but to the slips which have occasionally happened in mountainous countries. Strata are frequently in a highly inclined position, and if any of these should rest on a bed of clay, and the clay should be wetted by the percolation of rain or snow-water, there will be a great danger of their being thrown from the situation they occupy. An instance of this kind happened in September, 1802, in Switzerland. A mountain, called the Rossberg, five thousand one hundred and ninety three feet high, was composed of molasse and beds of clay, inclined at an angle of from 45° to 50°. By the percolation of water a bed of clay was softened, and the thick superincumbent beds, of molasse, losing their support were thrown or slipped off into the valley. By this accident several villages were overwhelmed, and from eight to nine hundred persons were destroyed. A similar occurrence happened in the year 1714, on the west side of the Diablerets, in the Vallais, and for two miles the surrounding country was so covered with blocks of stone and rubbish that the course of rivers was stopped, and lakes were formed.

DESTROYING EFFECTS OF FROST.

The expansion of water when freezing is a fertile source of destruction to rocks. In cold regions this is not an unimportant agent in altering the superficial appearance of the country. Water, when flowing over a district, produced perhaps by the thawing of the snow, enters the fissures, and when cold returns freezes, in which it acts as a wedge, and tears open masses of enormous size. Large blocks are thus separated from the parent rock, and dreadful accidents from their fall are not uncommon in Alpine countries.

The motion of ice when floating over the surface of water may also be mentioned as a cause of the destruction of rocks; but glaciers are the most powerful agents, and produce great effects when moving downward from the mountainous countries in which they are formed. "The glaciers of the Aar, in Switzerland," says a modern traveller, "which we visited from the Grimsel, presented a scene which I am convinced the world cannot equal; which none who have beheld it can ever forget, and those who have not seen it can even conceive. You cannot picture the scene; but you may form some idea

of the awe-struck astonishment which filled our minds when, after surmounting all the difficulties of the way, we found ourselves standing amidst a world of ice, extending around, beneath, above us,—far beyond where the straining sight, in every direction, vainly sought to follow the interminable frozen leagues of glaciers, propt up in towering pyramids, or shapeless heaps, or opening into yawning gulfs and unfathomable fissures. The tremendous barren rocks and mountains of the impenetrable Alps, amidst which the terrific Finsterahorn reared his granitic pyramid of fourteen thousand feet, appeared alone amidst this world of desolation. Eternal and boundless wastes of ice,—naked and inaccessible mountains of rock, which had stood unchanged and untrodden from creation, were the only objects which met our view. Hitherto, with all that we had seen of desolation and horror there was some contrast, some relief. The glaciers of Chamouni are bordered by glowing harvests; the glaciers of Grindelwald are bounded by its romantic vale; the glaciers of the Scheideck shine forth amidst its majestic woods. Even among the savage rocks and torrents of the Grimsel, though animated life is seen no more, the drooping birch, and the

feathery larch protrude their storm-beaten branches from the crevices of the precipices; and the lonely pine tree seen on high, where no hand can ever reach it. But here there is no trace of vegetation, no blade of grass, no bush, no tree; no spreading weed, or creeping lichen invades the cold, still desolation of the icy desert. It is the death of nature! we seemed placed in a creation in which there was no principle of life; translated to another orb, where existence was extinct, and where death, unresisted, held his terrific reign. The only sound which meets the ear is that of the loud detonation of the ice, as it bursts open into new abysses with the crash of thunder, and reverberates from the wild rocks like the voice of the mountain storms."

The little village of Randa, in Switzerland, is situated in a valley beneath a high mountain called the Weisshorn, the highest peak of which is 9000 feet above the village. This mountain is covered with ice and snow, but at various times portions of the vast glacier have been loosened and precipitated with tremendous violence into the valley. An accident of this sort occurred in 1636, when thirty-six persons lost their lives; and others in 1736 and 1786. On the 27th of December, 1819, at six o'clock

in the morning, a large projecting part of the glacier fell on a mass of ice with a frightful crash. The snow, ice, and stones, covered the fields below the village for a length of about 2,400 feet, and for a width of 1000 feet. The village itself was not injured by the fall, but a frightful hurricane was produced by the sudden disengagement of the immense masses of ice; the largest larch trees were torn up by the roots; blocks of ice many feet thick were thrown to the distance of half a league beyond the village; the spire of the church was carried away; the crops were destroyed; houses and other buildings levelled to the ground, and many persons injured or killed. Several families were carried away with their houses, and buried in their ruins or in the wreaths of snow.

We might here introduce some remarks on avalanches, but we will merely quote one passage from Simond.

"We sometimes saw a blue line suddenly drawn across a field of pure white; then another above it, and another, all parallel, and attended each time with a loud crash like cannon, producing together the effect of long protracted peals of thunder. At other times these portions of the vast fields of snow, or rather snowy ice, gliding

gently away, exposed to view a new surface of purer white than the first; and the cast off drapery, gathering in long folds, either fell at once down the precipice, or disappeared behind some intervening ridge, which the sameness of the colour rendered invisible, and were again seen soon after in another direction, shooting out of some narrow channel a cataract of white dust, which, observed through a telescope, was, however, found to be composed of broken fragments of ice or compact snow, many of them sufficient to overwhelm a village if there had been any where they fell. Our guides assured us that pushing with your foot against the edge of a beginning cleft in a bed of snow is often sufficient to determine the fall of an avalanche; that is, the sliding of the newer over the elder bed of snow. The discharge of a gun, gingling of the bells of mules, the voices of men, may be attended by the same consequences."

There is a very remarkable subterranean glacier at Fondeurle, in the south-east of France About twelve miles from Die, in the department of the Drome, there is an extensive meadow, called the Fair of Fondeurle, because the cattle dealers from the neighbouring mountains annually bring their flocks to this plain for sale or

exchange. Near to the fair are many extensive caverns, one of which is called the Glacier of Fondeurle. The cavern is about two hundred feet deep, and of very irregular width. The interior is decorated with stalactites of a crystallized lime, resembling in form icicles hanging from the projecting ledge of a building, or the overhanging roof of a cottage. These icicles (which, when formed of any other substance than congealed water, are called stalactites) descend from the vault to the floor of the cavern. One of these pillars of ice being cut by a gentleman who visited the spot, and a light being placed in the inside of it, the cavern was instantly illuminnated with various brilliant tints of yellow, blue, green, and red, and the eyes of the spectators were dazzled with the magical effects of the reflected rays playing upon the floor of ice, and upon the pillars of alabaster. Their admiration, however, was still greater, when having detached some of the pillars of ice they found the interior studded with the finest crystals of ice. This unexpected appearance induced them to examine more narrowly the pavement of ice upon which they trod, and they were surprised to find it composed entirely of crystallized portions, of the most perfect transparency."

From this account it appears that the action of frosts is not confined to the surface, and wherever a great alteration of temperature occurs, it must have a tendency to disintegrate them. We can trace its influence on our own coasts, and on the unimportant mountains which diversify the surface of our country; but to know the extent of its power we must watch the changes that are going on in polar and Alpine climes.

The chemical destroying effects of water are not very striking; they belong to that class of results only seen occasionally, and perhaps would scarcely be discovered if the observer were not directed in his research by previous knowledge. When water percolates through rocks, it must often come into contact with substances that it is able to take up in solution; and if the water should contain any adventitious ingredient, a chemical action may be produced. Lime is one of the most abundant substances in nature, and it is that one most frequently acted upon by water, when percolating through strata. The calcareous deposits thus formed at the places where the streams flow out are in some parts of the globe extensive. Salt is another substance readily dissolved, and considerable changes are thus made in the interior.

ROCKS FORMED BY THE ACTION OF WATER.

Having explained the manner in which rocks are destroyed, we must now attempt to show what is done with the disunited fragments, the places where they are deposited; and how they produce rocks. To trace the progress of the detritus from one situation to another, and follow it to the place where it is accumulated is not a difficult task, but one which could only be done by alluding to many examples, and entering fully into the inquiry. It will, however, be possible in the limited space offered in the following pages to show how the agent so actively employed in destroying rocks may be made instrumental in their reproduction.

By atmospheric causes, springs, glaciers, and other agents, rocks are disintegrated. The destroyed materials thus produced are brought into the valleys by streams of water, which, joining other streams, form rivers. Hence, then, it would appear that much of the detritus formed on the land must be carried into neighbouring rivers. Let us now enqnire how they dispose of it, and the effect of the streams on their own banks.

Many rivers when flooded overflow their

banks, and cover the surrounding country with water. This, as already stated, occurs annually with those rivers which take their rise in tropical countries. The Indus, during the rainy season, spreads over a distance of thirty or forty miles from its banks, and the Ganges, when it inundates the surrounding districts, has a breadth of one hundred miles, and a depth of nearly twelve feet. During this time the fine earthy or sandy matter suspended by the water, and brought down from the high country, is deposited. A soil about four inches in depth is formed in this way every century. In these rivers, where the amount of detritus is great, and the velocity small, much will be deposited in their own beds. Many rivers have in this way filled up their courses, and some are now in the process of doing the same.

At the places where rivers enter lakes or the sea, tringularly formed pieces of land are produced, and from their resemblance to a Greek letter are called deltas. "These deltas," says professor Jameson, an eminent naturalist, long and honourably connected with the progress of Geology, "are more strongly marked in lakes than in nearly enclosed seas, as the Mediterranean; and in these seas than in the ocean,

where the depositions are much interrupted by currents. The Ganges, a river estimated to carry 6,368,077,440 tons of mineral matter into the sea every year, has formed a delta which commences 200 miles from the sea. The Ganges discharges itself into the Bay of Bengal by numerous channels, called the Gunderbunds; but so great is the accumulation of sand in them, that large vessels can only enter by the Hoogly branch, which passes by Calcutta. The delta of the Nile, which is known to have been considerably enlarged since the time of Herodotus, is a remarkable instance of the deposition of detritus. The Mediterranean Sea, at that part immediately beyond the Delta, has a depth of about seventy-two feet; but beyond the action of the river it suddenly obtains a depth of about 2000 feet, which may be supposed the original sounding of that part of the sea now filled with detritus. The deltas of the Rhone and the Po also afford interesting examples of the influence of rivers in the deposition of detritus and the formation of new lands at their mouths.

The alluvial matter brought down by rivers not only forms great tracts of land at their mouths, but also extensive banks and shoals in

their basins. In proof of this statement, we have only to look at a chart of the German Ocean, one-fifth of which is at the present moment encumbered with deposits of sand and clay, formed from the detritus brought into it by rivers, and resulting from the action of waves upon the coasts. Other seas are loaded in the same manner, though not visibly to the same extent. One of the sand banks of the German Ocean extends in a north-easterly direction from the Frith of Forth to a distance of one hundred and ten miles. The Dogger Bank is still larger, extending for a distance of more than three hundred and fifty miles. The average height of these banks is estimated at about seventy-eight feet, and they are composed of siliceous sand.

Some rivers flow into lakes, and carry with them a large amount of detritus. Several lakes in Switzerland are from this cause in the process of filling. Many of the ancient lakes were loaded in the same manner with the destroyed material brought into them by the rivers then existing, and the strata are crowded with the remains of lacrustine animals.

While speaking of the formation of strata in rocks, it may be proper to mention that some

mineral substances are occasionally formed which must be attributed to chemical causes. "The bag-iron-ore," says Dr. Jameson, "or hydro-phosphate of iron, is often found in such situations as to show that it has been deposited from the waters of lakes; and in some countries it is collected from the sides and bottoms of lakes once in a certain number of years; thus showing that it is still forming in such situations. In salt lakes considerable depositions of salt take place; and when such collections of water dry up, or are drained off, the side and bottoms of the hollows are found incrusted with salt, which is sometimes disposed in beds alternately with beds of clay."

Some lakes have evidently been produced from volcanic action, and in them the phenomena are, as might be expected, singular, and different from those observed in other situations, especially when the igneous agent retains any degree of activity. The Lake Asphaltum, sometimes called the Dead Sea, is of this kind. It is commonly supposed to occupy that spot on which the cities of the plain, spoken of in the first book of Moses, stood. According to one theory, the lake was formed by the ejection of a current of lava, sufficiently extensive to stop

the course of the Jordan; but we are much more inclined to believe that the place on which they stood sunk into the earth, as happened at Euphemia, a stagnant lake being at the instant formed; but not without the activity of the volcanic cause to which earthquakes are attributable. The present appearance of the district is sufficient to prove that volcanoes have existed, and that lavas have been ejected by them; the extent of the catastrophe, and the probable circumstances, are yet to be determined.

The size of the Lake Asphaltum has not been determined with any degree of accuracy: according to Josephus, it is seventy-two miles long and eighteen broad. The Jewish historian, Tacitus, and many modern authors, have asserted that no fish can live in the water; but Maundrell observed some shell-fish resembling oysters on the shore; and Bishop Pococke was informed by a monk that he had seen fish caught in it. Writers have also stated that plants cannot grow either in or near it, but we have had an opportunity of seeing and analyzing specimens gathered on its shores. The coast is still subject to earthquakes; pumice is found on its banks, and bitumen floats over its surface.

Both sulphur and bitumen are found in the neighbouring mountains.

In conclusion, we shall only speak of the formation of downs and the drifting of sand as another means by which the appearance and superficial character of a district may be changed. The flowing in of the sea towards the shore brings a mass of sand, which, when left dry by the tide, is thrown by the wind upon the beach; ranges of sand hills are thus formed upon the coast. "Westward from the mouth of the river Findhorn, in Morayshire, a district consisting of upwards of ten square miles of land, which, owing to its fertility, was once named the granery of Moray, has been depopulated, and rendered utterly unproductive by the sand-flood. The barren waste may be characterised as hilly; the accumulations of sand composing these hills frequently varying in their height and likewise in their situations."

From the few facts here stated, and from a general view of the influence of water in destroying and reproducing rocks, there can be no doubt that many deposits are at the present time in the process of formation, and it is possible they may, at some future time, be elevated above

the level of the ocean. Should this ever happen they will present an appearance similar to that of modern rocks, and contain the remains of animals now existing. In the deposits formed at the bottom of rivers and lakes, the relics of terrestrial and fresh-water animals will be found; while, in those produced in the ocean, the remains of marine animals will be discovered; while, in the deltas, the two classes must be in some degree blended. These facts and deductions will, it is hoped, assist the student in following us through a short description of the various rocks composing the crust of the earth and the fossils they contain.

CHAPTER IV.

THE INFLUENCE OF VOLCANOES ON THE SURFACE OF THE EARTH.

In this country we are happily unacquainted with the terrible effects produced by volcanoes, except through the descriptions of travellers, who, visiting other climes, have witnessed those terrible eruptions by which human life is often sacrificed, and the character of a district entirely changed. The mountains and hills of our native land are never seen to open and discharge a volume of smoke accompanied with streams of lava; from them we never hear the deep rolling sound of an earthly thunder. With a conscious security we walk over the soil, feeling certain that we are not deceived in trusting to the stability of the earth, nor is this feeling ever disturbed by a sudden motion of the ground prostrating all that is upon it, and sometimes

swallowing cities and towns, sinking and raising mountains, spouting out streams of water, and forming large stagnant lakes, or closing over rivers which have for ages fertilized the plains through which they flowed. But there are countries where all this and more has happened.

The number of active volcanoes on the earth is but small, when we consider the immense superficies of our globe; there are not authenticated accounts of more than two hundred. But in forming an estimate of the extent of volcanic action it is necessary to keep in mind, that in the interior of the Americas, and other uninvestigated districts, many volcanic mountains may be hereafter discovered; and that it is by no means improbable, that some of those which are now considered extinct may again break forth.

To give the reader a general acquaintance with the action of volcanoes, and their probable influence on the surface of the earth, it may be desirable to trace their geographical position, describing a few remarkable eruptions. We will commence with Vesuvius, in the kingdom of Naples. The first recorded eruption of this mountain was in the year 79, when the cities of

Herculanœum and Pompeii were destroyed. Some celebrated writers of the present day are of opinion that Vesuvius did not exist till that period, and that the eruption which buried those devoted cities formed it. This probability is strengthened by the fact, that the measurement, as stated by ancient writers, from Pompeii and Stabia to a mountain in the vicinity, is only true when taken to the foot of Mount Somma. Hence, it is probable that Somma was destroyed by the eruption in the year 79, and that Vesuvius was formed by successive discharges of lava. After this period it was not in action till the year 203. In 472 it was violently agitated, and covered nearly all Europe with its ashes, but did not again eject lava, though it was in activity in the years 512, 685, and 993. From the year 1109 till 1306 it continued at rest; and during the latter part of this period was covered with vegetation. In 1611 Braccini examined the crater, that is to say, the opening, mouth, or vent of the mountain, and it was again covered by trees; but it suffered eruption in 1631; and also in the year 1660, 1682, 1694, and 1698: — since the last named year, its periods of quiescence have been comparatively short.

The eruption of Vesuvius in 1794 was one of extreme violence, and so terrible were its effects, that it may be desirable to give a short account. A severe earthquake was felt at Naples on the night of the 12th of June, but when this had passed nothing occurred to create any feeling of alarm in the minds of the inhabitants until the evening of the 15th, when the earth was again shaken by subterraneous forces. Soon after this had happened the eruption commenced. An opening was formed on the western base of the mountain, 237 feet broad, and 2375 feet in length. From this fissure a stream of lava flowed, and in the course of its progress divided into three currents, one of them flowing towards the town of Torre del Greco, which was in fact destroyed by the heated lava. The dreadful scenes which followed the eruption cannot be adequately described. "The fiery ejections of Vesuvius, the flames of the burning Torre, the groans of the mountains, the deathlike stillness of the atmosphere, and the cries of the thousands who had been driven from their homes and all the comforts of life, must together have presented a picture which no imagination can realize."

In the bay of Baiæ we find another volcano, Monte Nuovo, which was formed in the year 1538. It has not since that time been active, and the only evidence of the continued existence of the internal agency has been the emission of a thin vapour from the base of the crater. This circumstance, however, connected with the fact, that the hot baths of Nero are in the immediate vicinity, is sufficient to prove that the volcanic agency is still present. Between the Monte Nuovo and Puzzuoli there is a hill called the Golfatara, supposed to have been in a state of eruption in the twelfth century, but since that time, it has only given off gases and vapour.

There are several other volcanoes in the district round Naples, and in the neighbouring isles of Procida and Ischia. The latter island was the seat of volcanic agency in the fourteenth century; but its eruptions appear to have been from fissures. "In the basin of the Mediterranean," says Humboldt, "not only does the volcanic fire escape from permanent craters of isolated mountains, which have a constant communication with the interior of the earth, as Stromboli, Vesuvius, and Etna, but at Ischia,

in Mount Eponice, and according to the accounts of the ancients, in the plains of Selantis, near Chalcis, lavas have flowed from fissures, which have suddenly opened at the surface of the ground." The volcano of Ischia was once very active. Strabo says that the colony sent over by Hiero was so alarmed by the frequency of the earthquakes that the intended settlers could not be induced to remain on the island.

In the Lipari isles, between Naples and Sicily, there are two active volcanoes, Stromboli and Volcano. The island of Stromboli (Fig. 3, Pl. 2) is a large conical mountain, having on one side several small craters; one of which is in perpetual eruption. This small but interesting volcano is frequently mentioned by the ancient Greek writers, and particularly by Diodorus Siculus, and the learned Strabo. It has been in nearly the same state for more than two thousand years.

The island of Volcano, like all others of the Lipari group, is entirely volcanic; and, from the testimony of Strabo, seems to have been the seat of more violent eruptions than Stromboli. Its crater is situated on the highest elevation in the island, and still emits gaseous exhalations in so

great an abundance that it has been sometimes described as active.

From the Lipari isles we pass on to Sicily, the seat of the celebrated Mount Ætna. Those who have received their earliest impressions of this district from the writings of the ancients may perhaps expect a detailed history of this volcano, as some of the most interesting classical tales can only be understood by reference to this mountain and the neighbouring Cyclopean islands; but our remarks must necessarily be brief.

Ætna rises to the height of 10,000 feet above the level of the sea, and its base is 180 miles in circumference. It is surrounded by small volcanic cones, though of no inconsiderable size, which tend to increase the apparent dimensions of the central mountain. Some of these cones are covered with vegetation, but others are arid and bare. From this variety in the progress of vegetation, some persons have endeavoured to calculate the relative ages of the cones; but the results cannot be depended on; for a longer period will be required to form a soil on some lavas than on others; and situation must have some influence. Thucydides, a Greek historian, says, there were three eruptions before the Peloponnesian war (431 B.C.); and another

Greek writer informs us, that the Carthaginian army was stopt by the lava when marching against Syracuse. Since this period the eruptions have been very numerous, and some of them have been attended by the most awful phenomena.

From the island of Sicily we pass on to the Grecian Archipelago, which has at various times been the seat of violent volcanic action. The epoch of the eruptions at Milo cannot be determined; but there is every reason to believe that the volcanic force is still slumbering beneath its surface, and may break forth again. The island of Santorino also, formerly known by the name of Thera, is volcanic; and, according to Pliny, rose out of the sea in the 135th olympiad, or about 237 years before Christ.

Iceland is an island peculiarly subject to the devastating effects of volcanoes; indeed it is more remarkable than any other portion of the earth, both for the number of its cones and their frequent activity. Hecla, the most celebrated volcano of this island, has suffered thirteen eruptions since the year 1137, and during the last eight hundred years there have been twenty-two. After the eruption of 1766, it remained quiet until the year 1821.

The other volcanoes of Iceland have been the sources of violent eruptions, and have spread their lavas almost over the entire island, which seems to be a mere vent of some vast reservoir of melted rocks.

On the 25th December, 1821, a very remarkable fall of the barometer was observed throughout Europe, and in some places a singular agitation of the magnetic needle. These circumstances induced many persons to believe that a tremendous convulsion of nature had visited some parts of the globe; and such was the case, for the old volcano of Eyafjeld Jokkul had been a few days before in violent eruption. It commenced on the 19th of December, and a crater or opening was formed through rocks and a thick covering of ice. A mass of ice, 18 feet high and 60 feet in circumference, was thrown to a great distance; and a heated mass of rock, weighing fifty pounds, was found at a distance of five miles from the volcano. A lofty column of flame was also seen issuing from the opening, and so intense was the light that the people were able to read in their houses by night as if it had been day. On the 20th of December, the day after the eruption, the air was filled with a fine powdered pumice, which

fall all over the island like snow. On the 25th of December, a violent storm raged from the south, and cleared the fields of the sulphureous dust that covered them.

The only other situation in Europe in which an active volcano has been found is the island of Jan Mayen, off the coast of Greenland, which was in a state of eruption in the year 1818. When visited by Captain Scoresby, the crater was 500 feet deep and 2000 feet in diameter.

The continent of Africa does not offer a single example of an active volcano; but nearly all the islands are of volcanic origin, and many of them are active. The whole group of the Canaries has been produced by the ejection of lava through the waters of the ocean.

Our attention is first drawn to the island of Teneriffe, the peak of which is one of the most elevated volcanic mountains in the world, for it lifts its towering head to a height of 12,176 feet above the level of the sea. It is like a vast pyramid: its base is more than 115,000 yards in circumference. The cone is small in comparison with the mountain, and is said to be not more than 537 feet high. Its crater is about 300 feet in its greatest, and 200 feet in

its least diameter, and 100 feet deep. It is not, however, from this that the eruptions proceed, for it has not been active since the island has been inhabited. Eruptions from the side of the mountain have not been uncommon, and especially from the mountain Chahorra. In the year 1706 an eruption destroyed the harbour of Garachico, which was the finest harbour in the island; and at that time the lava was observed to travel at a rate of nearly three miles an hour. The last eruption from the crater of Chahorra was in 1798, when it threw out lava and ashes for the space of six months.

In the island of Palma there is a conical mountain, and the cavity forming the crater is 5000 feet deep: it was in a state of eruption in 1677.

Lanzerote has also been the site of most terrific volcanic action; its last eruption continued from the first of September, 1730, to the 16th of April, 1736. Von Buch has given an interesting account of the phenomena which attended and followed this violent effort, and also a description of the vent itself. The crater is walled in by precipitous rocks; and in the interior two other craters have been formed. A space of three square miles on the west is

covered by a mass of black lava. This, however, was not the only opening from which the melted rocks were thrown. "How much was I astonished," says Von Buch, "when, on reaching the summit, I perceived an entire series of cones, placed so directly in a line that the nearest covered the farthest one in such a manner that their summits alone were seen peeping from behind."

The island of Ferro has a volcano which was active, in 1692, for a continued period of six weeks.

The only island among the Cape de Verde group that has an active volcano is that of Fogo, or Fuego; but as little is known concerning it we may turn our attention to the Azores, all of which are of volcanic formation, and some contain active mountains.

In the isle of Bourbon there is a volcano which is constantly active. St. Michael's island, which is the largest of the group, has frequently been the scene of eruption. The last recorded instance of activity happened in the years 1810 and 1811. In the beginning of the latter year an island was formed about two miles from St. Michael's, consisting of a crater 500 feet in diameter; but it has been gradually worn away

by the action of the waves, and is now beneath the level of the sea. In El Pico there is a volcano which was active in 1718, but since that time has not been disturbed. The islands of San Georgio and Fayal have each a volcanic mountain. Ascension and Madagascar contain extinct volcanic cones; but the volcano of Jibbel Teir has been recently active.

The volcanoes of Asia, as well as those of Africa, are confined to the islands, with the exception of Kamtschatka (the whole of which has been probably formed by a volcano), and, we may perhaps add, Mount Elbourz, in Persia, the mountains of Tourfan and Bisch Balikh.

The principal volcanoes of Kamtschatka are called by the natives Awachinski, Tulbatchinski, and Kamtschatka mountain. Awachinski is situated to the north of the Bay of Awatcha. One of the earliest eruptions with which we are acquainted was that which happened in 1779, when Captain Cook was off the coast. But its most violent effort was in the year 1737, which was followed by a tremendous earthquake and encroachment of the sea; although it afterwards receded and united the first and second Kurile Isles with the continent. Tulbatchinski is

situated between the rivers Kamtschatka and Tulbatchik. It was in violent activity during the year 1739, and has ever since emitted dense vapours. The Kamtschatka mountain is the highest elevation in the country. It burst forth in 1728, and again in 1737; and since the last named period it has not ceased to eject ashes three or four times a year. To these may be added several other active volcanoes, but little is known concerning them.

From Kamtschatka we may proceed to the Kurile Isles, where there are not less than nine active volcanoes; and from thence to the islands of Japan, where there are ten. In the island of Niphon alone there are three. It seems to have been at one time connected with Jesso; but however this may be, they are now both under the influence of the destroying agent.

The number of active volcanoes in the archipelago of Javan, and an examination of the islands has convinced many voyagers that the present state of the "sea of islands" may be traced to the action of volcanoes. In the year 1803 the Russian government intrusted to captain Krusenstern the command of some vessels fitted up for a voyage round the world. This celebrated navigator, and Dr. Tilesius, who was appointed to the situation

of naturalist, have given an interesting account of the volcanoes in and near Japan, and especially of one in the island of Coosima. This is supposed to be the smallest volcano in the world, consisting only of a pointed rock rising about 150 fathoms above the level of the water. Dr. Tilesius says that the ship in which he sailed went three times round, and so near, that from the mast he could look into the aperture at the summit, and could with great ease have thrown a stone into it. Figure 3, Plate 2, is a view of the island and the volcanic crater. The volcano of Oosima, a neighbouring island, is, like its companion, constantly pouring out volumes of smoke, and has evidently been the theatre of violent eruption.

In enumerating the other volcanic islands till we come to Sumbawa, the reader will do well to have a map before him, so as to gain some notion of the vast extent of that terrible agent which breaks up the solid crust of the earth, pours upon the surface floods of liquid rock, and raises from vast depths in the oceans the islands which in the course of years are converted from barren rocks into fertile fields.

As we proceed from the south of Japan, we come to the Sulphur Isles, in the Loo-choo

group, and Formosa, both of which emit sulphureous vapour, and bear evident marks of present activity.

Many of the Philippine Isles have volcanic cones. In Manilla there are several, in Luçon three, in Fuego one, and one in Mandanao, which suffered a violent eruption in 1764. Borneo is said to contain several volcanoes, but their position is doubtful.

Barren island, one of the Andamans, has a mountain nearly 4000 feet high, from which immense masses of rock, some of them three or four tons in weight, are thrown.

The Moluccas abound with volcanoes, and the Celebes also have many. In the island of Sanguir, between Mindanao and Celebes, there is one of the largest in the world. Of these but little is known.

One of the most violent volcanic eruptions ever known happened in the island of Sumbawa, in April, 1815. There is in this island a mountain called Tanbora, which rises to the height of nearly 7000 feet above the level of the sea. From the 5th to the 11th of April the mountain was greatly disturbed: dust was thrown out, and loud sounds, produced in the interior, were heard, not only in the vicinity

but even to a distance of sixty miles. On the night of the 10th and morning of the 11th of April, the loudness and frequency of the reports increased, being like the discharge of large cannon close to the ear. At seven o'clock on the morning of the 11th the clouds of dust were so thick as to produce a total darkness, which continued till seven in the afternoon of the 12th. Three distinct streams of lava were thrown out from the crater, and the town of Tanbora, situated at the bottom of the west side of the mountain, was swallowed up by the sea. Thousands of the inhabitants, and of the horses, in which they chiefly traded, were killed, and all traces of vegetation so completely destroyed that of those who were spared after the eruption many died from starvation, and others were compelled to seek shelter and support in some neighbouring country. During the eruption there was no wind, but the sea was so violently agitated that many houses were washed away, and several large trading boats at anchor in the bay of Beema were thrown on shore. The dust found lying on the ground at a place some distance from the mountain was three inches thick.

From these particulars we may form some idea

of the great violence of the eruption, but who can realize by the exercise of imagination the horrors of the scene? the tremendous explosions (which were heard at a distance of more than nine hundred miles), the thick darkness, the currents of liquefied rock, the raging of the sea, the burning vegetation, and the screams of men and animals. In a few days a rich and even luxuriant country became a barren and sandy wilderness, and thousands of the inhabitants perished on the soil they had cultivated, or in the dwellings they had reared. Such terrible visitations as those we have just described bring to mind the exclamation of an inspired poet:—

"Oh that thou wouldest rend the heavens, that thou wouldest come down, that the mountains might flow down at thy presence, as when the melting fire burneth, the fire causes the waters to boil, to make thy name known to thine adversaries, that the nations may tremble at thy presence. When thou didst terrible things which we looked not for, thou camest down, the mountains flowed down at thy presence."

Java has eleven active volcanoes. Payandayang was one of the largest mountains in this island; but in 1772 it was entirely carried away by a violent explosion. The cavity thus formed measures fifteen miles by six.

There are four volcanoes in Sumatra, and two in New Guinea, which were burning when Dampier explored the coast in 1700; and several others have been observed in the New Hebrides, Friendly, and Ladrone islands. Owhyee, one of the Sandwich isles, contains an active cone, which has been described by the Rev. W. Ellis in his interesting work. The Rev. C. Stewart has also published an account of his ascent to the great volcano of Kirauca in this island. The opening is not like a basin as others are, but an immense chasm in an upland country, near the base of the mountain Mouna Zoa, which is between 16,000 and 18,000 feet high. It is not approached by ascending a conical mountain, but by descending two vast terraces; and is not visible from any point at a greater distance than half a mile. It is probable that it was originally a cone, but assumed its present aspect (it may be centuries ago) by the falling in of the summit.

For the knowledge we have of the volcanoes of the American continent we are indebted to Baron Humboldt; but notwithstanding the indefatigable industry of this celebrated naturalist, there are probably many of which we have not heard. There are three active volcanoes in

California. Mount Saint Elia rises to the height of 17,875 feet above the level of the sea.

The five active cones of Mexico are situated in a line, and appear as if connected with an interior reservoir traversing the country from west to east. Of Jorullo, one of these, a short account may be given.

Before the year 1759 the space which is now occupied by the mountain Jorullo was a cultivated plain, though from the character of the rocks there is every reason to believe that it had been at some former period under the influence of the internal fires; but no information concerning this can be obtained from the traditions of the inhabitants.

In June, 1759, loud rumbling sounds were heard, and frequent earthquakes succeeded, which continued nearly two months, but in the early part of September had entirely ceased, and tranquillity seemed to be restored. On the 28th of that month the noises were again heard, and during that and the following day a space of ground from three to four miles in extent was elevated in the form of a bladder. At the same time flames issued from a space about half a square league in superficies, and large

fragments of rock were ejected. The rivers of Cuitimba and San Pedro were precipitated into the chasm, and seemed to increase the violence of the eruption. From the plain, thousands of little cones, called hornitos *(ovens)* by the natives, were formed, and columns of smoke were projected. In the midst of this, six larger cones were thrown up in the line of the chasm, the least being three hundred feet above the level of the plain. Jorullo, the largest, is sixteen hundred feet. From this elevation immense quantities of lava and rock were thrown into the air almost without intermission, till the following February, when the action became less violent.

Humboldt visited this mountain twenty years after the eruption, and the lava was then hot. Since that time it has been again active; but although this happened in 1819, no authenticated information concerning it has reached us.

In the provinces of Guatimala and Nicaragua, which lie between Mexico and the Isthmus of Darien, there are twenty-one active volcanoes, and all of them situated between 10° and 15° of north latitude. On the southern side of the Isthmus, in the provinces of New Granada and Los Pastos, there are several others; and in the

neighbouring province of Quito we come again upon an interesting series. Antisana, which is about 18,000 feet above the level of the sea, was active in 1590.

In several of the Leeward Isles we find volcanic mountains. St. Vincent has one active cone, called Le Souffrier. Its first eruption of lava was in 1718, which, like that of Tomboro, was accompanied by a hurricane. In 1812 it was again active, and before the eruption the surrounding country was agitated by two hundred shocks of earthquake, by one of which the city of Caraccas was destroyed.

The needles of St. Alousie, in the island of St. Lucia, are volcanic rocks. "In one deep valley at their foot," says Raynal, "there are eight or ten ponds, the water of which boils up in a dreadful manner, and retains some of its heat at a distance of 6000 fathoms from its reservoirs."

The beautiful and romantic islands of Nevis, St. Christopher's, Guadaloupe, and Montserrat, are all sites of volcanic action, and in the Aleutian isles there are no less than six active cones.

This brief review of the geographical position of the known active volcanoes is imperfect, but

it cannot fail to give some adequate notion of the extent of the subterranean fires. Those who have never witnessed the phenomena which accompany eruption, or examined the effects, are not perhaps able to conceive the power of this wonderful agent; but the review we have taken will preserve the reader from the error of supposing it partial in the extent of its action.

We might now proceed to speak of the influence of volcanoes upon the surface of the earth, but, before we do this, it may be desirable to make a few general remarks, the accuracy of which may be proved by what has been said in this chapter. But the reader will be best able to come to some general conclusions if he will mark upon a map of the earth the places which have active volcanoes, or give evidence by other means of the existence of great internal heat.

Nearly all volcanoes are either situated in islands or near to a large body of water. This fact has suggested to some writers the possibility that the eruption may be in part occasioned by the flowing of water into the interior of the earth. If it be admitted that the interior is greatly heated, and so much so as to cause the melting of rocks, the access of air and water would

be productive of effects having some resemblance to those which attend volcanic eruption. If water be dropt upon a mass of red-hot iron, or into a coal-fire, it will be converted into steam, a light and apparently powerless vapour; but, when it is confined, possessing an energy that would be sufficient to rend mountains, and toss into air the most dense and strongly resisting rocks. Whether this theory is sufficient to account for all the phenomena which attend volcanic eruption, we do not stop to enquire, and mention it merely to show that a reason may be given for the situation of active cones near to large reservoirs of water. There are, it is true, a few, such as those in Mexico, which are far from the sea, but there is strong reason to believe that they are also connected by internal channels.

It may be farther remarked that volcanic cones are generally either ranged in lines or in groups, from which it will appear probable that they are connected with some vast internal reservoir of melted rock. The volcanoes of South America, already alluded to, are situated, as it were, upon a comparatively narrow band crossing the continent and extending into the Pacific Ocean. So again proceeding from

Barren Island we may trace a complete chain of active volcanoes through Sumatra, Java, the lesser islands of Sumbawa and others, to the Philippine group. If we turn to the volcanoes of Europe, and trace their direction on a map, we shall be equally struck with this peculiarity of arrangement.

There has been much discussion among geologists as to the connection of volcanoes and hot springs. It is possible that the temperature of some springs may be raised by chemical causes altogether independent of internal heat. The hot springs of Bath, Clifton, Buxton, and other places, have been accounted for in this manner by some writers; but when we consider how violently the rocks have been there disturbed, it is at least possible that the cause producing volcanoes occasions them. There are, however, many instances in which the hot springs are situated in volcanic districts and near active cones, and of their origin there can be no doubt.

The hot springs of the island St. Michael are situated in the Valle das Furnas *(The Valley of Caverns)*. This valley is nearly circular, and about twelve miles in circumference. It is watered by numerous streams, which unite

and form the warm river. The hot springs are situated near one extremity of the valley, and not far from a few cottages, called the village of Furnas. The following description of the springs is obtained from Dr. Webster's account of the island, published in America; and we have extracted his own words, omitting such parts as would not be understood by those for whom we are writing.

"The springs are, not seen at any distance, being surrounded by small hills, some of which, there is great reason to believe, owe their origin in part, if not altogether, to the springs themselves. They are generally covered with short shrubs, but some of them are wholly devoid of any trace of vegetation. The vicinity of the springs is indicated by the increased temperature of the earth, a sulphureous odour, and the escape of vapour or steam from every crack in the ground. The temperature of the clay continues to increase as we advance, and a greater quantity of vapour is at last seen slowly ascending from the springs themselves.

"The volumes of smoke and steam rolling upwards from the surface to a great height, till they are gradually diffused through the atmosphere, or mingle with the heavier clouds that

crown the summit of the mountains, produce a striking effect. The confused rumbling and hissing noise that is heard for some time before we arrive in sight of the springs increases at last to an incessant and terrific roar, and seems to issue from the very spot on which we stand. The earth returns a hollow sound, and great caution is required to avoid stepping into the pools and streams of boiling-water, with which its surface is covered."

"The large springs are called caldeiras or boilers, and by the constant deposition of earthy matter shallow basins have been formed round them. The largest of these, which is circular, is between twenty and thirty feet in diameter. In this the water boils more violently than in any other, and at short intervals there are loud explosions proceeding from it. Immediately after the explosions there is a slight elevation of the water in the centre of the basin, and a loud hissing noise.

"A few yards from the principal caldeira is an elevation about fifty feet in height, and probably as many in extent. A few years since the side of this hill fell in, and discovered a deep and frightful cavern; smoke and steam at present issue from it in vast quantities, accompanied by a tremendous noise. The hill, indeed,

appears to be a dome, covering an extensive abyss, from which, by another outlet nearer the summit, hot mud and stones have been occasionally ejected. Looking down through the opening, a body of water is seen boiling with great violence. An appalling roar is incessantly reverberated from side to side within the dome, and is increased, at short intervals, by sudden and violent explosions. The surface of this hill, the sides of the cavern, and the innumerable crevices in the ground, are coated with sulphur; in obtaining specimens of which, I found the heat and acrid fumes almost suffocating."

The hot water of the springs contains a silicious, that is, flinty, and also a clayey substance, and these minerals are deposited wherever it falls or flows. Vegetables are frequently incrusted with these substances. All the various stages of petrification may be observed round the springs, in the grass and leaves which are sprinkled with the water; some being soft and differing but little from their natural state, and others partly converted into stone or entirely consolidated.

There can be no doubt that these hot springs are produced by the agent which forms volcanoes.

The quantity of mineral deposited by hot springs is much greater than any person could imagine. The hot springs of San Filippo, in Tuscany, have formed a hill of rock,* chiefly composed of lime, and as hard as limestone. That rock, called by the Italians *Travertino*, is formed by springs, and it is so abundant in south-western Italy that it is commonly employed for building. "The ancient temples, and the gorgeous palaces and churches of Rome, and, indeed, the whole of the streets and squares of the former mistress of the world, are built of concretionary masses, which have been deposited by springs." Near Guancavelica, in South America, the water contains so much earthy matter that the inhabitants receive it in square blocks or moulds, which are in a few days filled with the mineral substance fit for building. This is a curious but a very effective mode of brick-making.

Concerning the hot springs at San Filippo we must speak more particularly, which may be done, as Dr. Gosse has published an interesting account of his visit to the baths they supply. The hill on which San Filippo stands is com-

Technically called "Calcareous Tuffa."

posed of a mineral substance deposited by the hot water. The spring which supplies the baths of the village is less abundant than any other. The water is conducted into a pond, in which, after about twenty years, so much mineral matter, chiefly consisting of lime, had been deposited, that a solid mass thirty feet thick had been formed. From the pond the water "is conducted to work a mill, belonging to the surrounding villages. A second spring lies to the west of the village: it runs directly into the torrent without being employed: its temperature exceeds by a degree or two that of the former, which is 122.° Besides these two springs, there is a third on the top of the hill, which has formed for itself a small pond. It is as warm as the others, and is supposed to communicate with them." The mineral substance around these springs has been produced by them. Many deep fissures, especially near the second spring, have been observed; one is thirty feet deep, and between one hundred and fifty and two hundred feet long. It is almost filled with water, from which the vapour of water and sulphur arises.

The name of the village, and consequently of the springs, is derived from that of a Florentine

who hid himself at this spot, it is said, to avoid the honour of popedom, when Gregory the Tenth was raised to the chair. From a remote period it has been celebrated for its mineral waters. That the Romans constructed baths there is proved by the remains of Ionic columns, and the discovery of coins, and there can be little doubt that the springs were known to the Etrurians.

As the waters of San Filippo contain a large quantity of earthy matter, they may be employed for the purpose of taking accurate moulds or impressions of any work of art, and they have now for sometime been employed in the manufactory of medallions in basso-relievo. This application of a natural property for the purposes of art was first suggested and applied by M. Vegni, who intrusted the superintendence of the works to M. Pagliari, who gave Dr. Gosse a description of the process employed. From this account the following particulars are taken.

"As the water of the spring contains earthy substances of different qualities, some of which do not become very compact when consolidated, the first step is to separate these by precipitation and crystallization. With this view, the water is conducted from its source in small superficial

canals, in the course of which are three pits, two and three feet square, placed at the distance of five feet from each other. During its progress the excess of carbonic acid combined with the earthy matter escapes, and a portion of carbonate and large crystals of sulphate of lime are deposited in the pits. Thus freed from its grosser parts, the water is conveyed by a tube to the summit of a small chamber, from which it falls freely through a space of ten or twelve feet upon a frame work of wood of a pyramidal form, about two feet and a half high by one foot in diameter. Within the frame are disposed horizontally three series of flat cross sticks, placed about nine inches below each other; each series is made to cross in a direction different from the one above it, and the crossed pieces increase in number and size as they descend. By this arrangement the falling current is necessarily broken and dispersed with rapidity around the chamber. The moulds from which the casts are to be taken are formed either of plaster of Paris, sulphur, or, what is better, of glass. They are rubbed lightly over with a solution of soap, and are attached by iron wires to narrow pieces of board, which are disposed almost perpendicularly round the frame of wood, at the

distance of two or three feet. In this position they receive an equable and continued dash of water, in form of an artificial rain, during which, the deposition takes place, and the water rapidly escapes; — conditions all of which are necessary to obtain a solid and semi-transparent cast like marble. A reduction of temperature in the chamber is also required to favour the deposition, but a current of cold air is not admitted, both because it would prevent the equable distribution of the water, and render the cast itself brittle. The chamber, therefore, has openings only in its upper part, to permit the rapid escape of the contained vapours. The moulds are thus left exposed to the action of the water from ten or twelve days to two or three months, according to the size and thickness, or inequalities of the cast. A cast of two or three inches diameter requires a thickness of at least two or three lines; one of six inches, four lines; of one foot, eight lines. The casts are easily detached from the moulds, their edges clipped, and their front surface rubbed first with a subtile powder and water, and then polished with a paste composed of soap and calcined sheep bones. They thus acquire a smooth shining appearance, and their semi-transparency is improved, while the back

surface or reverse remains dull and rough." In a similar manner casts are taken of engraved metallic plates. Before a plate is exposed to the action of water, a little printer's ink is passed over it, so that when the cast is removed the engraving is represented by black lines on a white ground. The black lines are then separated by a knife, the cast is warmed, and printer's ink is rubbed over it, and will adhere to those parts only which have been scratched.

From this short account of volcanoes it will be evident that, whenever an eruption occurs it is always attended by phenomena which have some influence on the district. The ejection of lava is perhaps less to be feared than any other phenomenon by those who reside near an active volcano, and has only a slight effect upon the surrounding country. In estimating the influence of volcanoes in changing the surface of the earth, we must divest our minds of all the terrible circumstance by which the eruption is attended, and with a careful eye cautiously examine the difference between the spot before and after the catastrophe. A small space will probably be covered with the melted rock thrown from the crater, and its thickness may be considerable; cinders and the fragments of rocks may also be

thrown out, and not unfrequently cover a much larger extent of country than the lava itself; the earthquakes attending or preceding eruptions are still more influential in altering the external features of a district; but taking the largest view of the subject, and estimating the extreme effects, we shall necessarily come to the conclusion that the superficies of the earth is but little changed by volcanoes.

We may now close our remarks with a short account of another class of phenomena connected with volcanic eruption.

Some volcanic mountains are so lofty that a large portion of them is covered with snow. When any of these suffer eruption, and the crater is situated on or near the summit, violent floods always attend the ejection of lava. The snow is melted by the great heat, and the currents from various parts of the mountain, uniting, form torrents, and, rushing into the plains, devastate the surrounding country. Condamine states that during an eruption from Cotopaxi, a village thirty leagues distant in a straight line, and sixty following the wavings of the ground, was entirely destroyed by a torrent. These rushing streams of water are charged with earthy matter, and have therefore some effect in changing the

physical characters of a district. The great velocity with which they roll along must also give them a mechanical force, causing them to overturn and remove every obstacle that stands in their channel, and spread over a large district the wreck of their fury.

But it sometimes happens that torrents of hot water are ejected from either the crater or some other opening of a volcanic mountain. In the year 1751 a torrent of hot salt water was thrown out from Ætna during the eruption of the mountain, and continued to flow for a quarter of an hour. Many persons believe certain rocks to have been formed by the mineral substances contained in these torrents.

Cotopaxi, and other lofty volcanoes in South America, never eject lava, but ashes, pumice, and muddy water. "In the year 1698 the mountain of Carguarazo, near to Chimborazo, fell down, and covered eight square leagues with mud. In the earthquake of the 4th of February, 1791, forty thousand persons were destroyed by eruptions of water and mud. Muddy waters, resembling those which flow from volcanic mountains, are vomited forth in great quantities from districts where no volcanic rocks occur, when these are agitated by earthquakes or other causes.

In Peru and Quito the devastations occasioned by volcanoes are not caused by streams of lava, but by water and enormous streams of mud (called by the natives Moya), which present two remarkable phenomena, viz., an intermixture of inflammable matter and of fishes. The inflammable matter is so abundant that the inhabitants of the districts use it in the place of fuel. The moya which was thrown out after the terrible earthquake of 1797, and which inundated the country of Pelileo and destroyed the village of that name, was remarkable for its abundance of inflammable matter. Very often these streams of mud from the interior of the mountains bring along with them fishes about four inches in length, and the quantity is sometimes so considerable that their putrifaction occasions diseases in the country. Humboldt remarks that they are the same species as occur in the rivulets of the neighbouring country, and appear to find their way into the subterranean lakes by means of fissures in the rocks."

We may here speak of a class of volcanoes not hitherto described. There are in various parts of the world small conical mounds or hillocks, which throw out jets of water containing a large quantity of earthy matter, and are called air or

mud volcanoes. At Macalouba, in Sicily, there is one of these. Upon a hillock of hardened mud, about one hundred and fifty feet in height, a great number of small cones, about three feet high, are seen, and each of these has a crater containing mud, which is kept in a constant state of agitation, by the gases that are perpetually rising, frequently ejecting the mud, and consequently adding to the size of the hillock. Occasionally, these mud volcanoes exhibit more violent eruptions, preceded by phenomena somewhat resembling those which foretell the activity of the cones that eject lava. Earthquakes are felt for a distance of two or three miles round the spot; and immense jets of mud are thrown out, frequently accompanied by large masses of stone.

Professor Jameson has given an account of one of these eruptions, as described by an eye witness, and it is too interesting to be passed over in this place. "A dull noise was heard; the earth in the neighbourhood was much agitated, and large rents opened. There arose from the centre of the plain a bubble of diluted clay, sixty feet in diameter, which gradually increased in magnitude, and attained the enormous elevation of two hundred and thirty feet. This ex-

traordinary and striking spectacle continued for half an hour; was repeated three times, with an interval, between each, of a quarter of an hour; and, during its continuance, a stormy noise, like that of the sea agitated by a tempest, was heard to proceed from below."

These mud volcanoes are by no means so numerous as those which eject lava, and but few of them have been described by travellers. Humboldt speaks of some he met with in South America, and Dr. Ferguson, of a similar appearance in the Island of Trinidad. Their effect upon a district is considerable, and mineralogists by comparing their products with more ancient rocks have little doubt that they have been at former periods very numerous and active.

The description which has now been given of the present state of volcanoes, and their influence on the surface of the earth, will enable us to trace the operation of the same agent at earlier periods, and on rocks generally. In attempting to discover the origin of rocks, we are governed by appearances, and form our opinions by comparison. By an examination of the beds of clay and sand, limestone and gravel, formed in the beds of seas, rivers, and lakes, and even by springs, we are able to identify

them with similar deposits forming a part of the series we are accustomed to distinguish as the crust of the earth. And in the examination of rocks, many will be found so closely resembling those minerals thrown out by volcanoes, that it will be impossible to deny their origin from the same or an analogous agent.

The rocks supposed by geologists to be of volcanic origin are very different in appearance, and names have been given to distinguish one kind from another. It would be of little service to the reader were we at present to attempt an explanation of the peculiar characters of these rocks, for they will be more properly explained in another part of this work, but it may be desirable to allude to some of the forms under which they are presented to our notice.

The first and most evident result of a volcanic force must be the disturbance of the rocks lying above that part of the earth's interior where the force is active. The vapours and gases disengaged strive to escape, and exert so great a force that they crack the heavy and compact beds, and oftentimes raise immense masses of rock to great elevations, and form mountains or hills. Many examples of this might be given; — the country between Dart-

moor and the coast of Cornwall may be mentioned. Slate is the superficial rock of the district; that is to say, it lies, according to the order of rocks, above all the others. Violent forces have, however, been at some period active, breaking up this rock and causing the intrusion of granite. To explain this, let it be supposed that the mineral now forming the granite rock was at one time beneath the surface, and in a liquid state from excessive heat. As soon as the slate rock which covered it was broken, the liquid granite, being forced upward by the pressure of gases and vapours, would be thrown into the opening, and fill it up, in the same manner as lava now rises in a volcano. In this state it might either have flowed out of the opening, or by sudden cooling have been fixed and consolidated. These remarks will be easily understood from Fig. 1, Plate 3, which represents the relative position of the rocks, and exhibits in a striking manner the extent of the disturbance to which they have been subject. Yet not only has the granite been thus thrown to the surface, but also another rock, called greenstone, a variety of that class denominated trappean. This greenstone is found in a large mass at the summit, and has even

filled up the cracks and fissures made in the slate, and produced what are now called veins.

Many rocks contain veins, and these are filled with metals and other mineral substances. All the metals are not found in veins; sometimes they occur as bunches disseminated throughout the mass of rock, and sometimes as beds. The greater quantity of metal obtained in this country is collected from veins, and it is a remarkable fact that they generally run in a direction either east and west or north and south. The former are most rich in copper, the latter in lead, and are called cross veins. The veins thus running in different directions sometimes interfere with or cross each other, one or the other being turned out of its course. This frequently causes the miner great trouble, for after following a vein for a long time he suddenly loses it, and may spend many months in an unavailing attempt to find it again.

In Switzerland and other mountainous countries the influence of a vast internal force is very remarkably exhibited. Not only have mountains been elevated, but they have also been torn and contorted; the arrangement of rocks disturbed, beds twisted

and turned in various ways, and even broken asunder, to make way for the melted mineral mass, which could no longer be confined in the interior. Nor has it unfrequently happened that the rocks causing all this disturbance have in future times been compelled to give way to a fresh ejection; so that the appearance of a district, a country, and even a continent, may have undergone a series of changes.

The ancient volcanic rocks abound in the Western Isles, and often present a curious and beautiful appearance. Sometimes they have a flat step-like form, rising one above the other, greatly resembling works of art. At other times they have a columnar structure, as at the Giant's Causeway, in Ireland, Fingal's Cave, and the Point of Duin, in the Island of Sky. Many districts of great extent are entirely formed of the old volcanic rocks, and they are not unfrequently found to constitute the highest peaks of mountains and of mountain chains. From a comparison of them with modern rocks of the same character, we are led to the belief that the volcanic force has been in past periods of the earth's history much more active than it is now; and, although in the present day it does but little to change the superficial appearance,

it has been the main cause of those peculiarities so strongly marking the distribution of land and water, mountains and valleys.

CHAPTER V.

EARTHQUAKES.

Of all the phenomena which act upon the surface of the earth, and change the condition of districts, none are more violent, or apparently produce so great an alteration as earthquakes. But, in attempting to ascertain the influence of certain causes in altering the condition of the earth's surface (increasing the amount of land in one place and of sea in another; raising or depressing mountains, and in some cases completely changing the form of a country), we must always take into consideration the duration of their action. Earthquakes and volcanoes produce great changes in a comparatively short period of time; yet they are, perhaps, on an average, only exerting their influence for a few hours in the lapse of a century. It is easy, therefore, to determine the precise amount of physical action. We are all, for instance, so

well acquainted with the peculiarities of the country in which we are living that, if any great alteration should be suddenly made, it would be easy to form a comparison between what it was at one time and what it assumed at another. When the agents producing change are slowly but constantly acting it is not possible to form a comparison, and, although they may in a certain period of time do more to effect an alteration of form, it is not seen. A river, for instance, continues week after week, and year after year, to receive the streams which flow into it, with all their accumulations of soil; it also is constantly acting upon its own channel, widening it in one place and filling it in another, All this is done so gradually that those who are residing on its banks do not perceive any change. In the course of years, or perhaps of centuries, some one who refers to an old record, or to the traditions of the place, discovers that a long time since the river was much narrower and deeper, and that large vessels could float where a boat can now scarcely venture. This may happen, but it is seldom that the change is sufficiently rapid to give any person an opportunity of comparing the state of a district at any two short periods. The action is nevertheless

certain, and we may also add universal, for all countries have their collections of water. Earthquakes and other violent destructive agents are confined to certain districts, and are in action after long intervals, and, therefore, however terrible in their effects, do not produce so great an alteration of the surface of the earth as might be at first imagined.

Earthquakes are generally preceded by some remarkable atmospheric appearances, and not unfrequently by violent winds. Some days before the shocks of an earthquake are felt, the sky usually presents an exceedingly wild and unsteady aspect; dark clouds are seen flying to and fro over the heavens, sometimes whirling round, and at other times meeting apparently with great force. Terrible hurricanes frequently attend these awful prognostics. When the violence of the wind ceases an unnatural calmness of the air follows, strange agitations of the sea, the sudden bursting forth of hot and sulphureous springs, deep rumbling sounds and violent explosions, resembling the discharge of artillery.

Earthquakes are usually attended or followed by the bursting forth of volcanoes, sometimes at a great distance from the places most affected

by the shaking of the earth. In the year 1823 Lima was entirely destroyed by an earthquake, and four volcanic openings were, on the same night, formed in the Andes. This dreadful occurrence happened on the 30th of March, and the weather was at that time remarkably fine and clear; but about half past seven o'clock a light cloud passed over the town, and a noise resembling heavy distant thunder was heard. The shaking of the earth followed, the churches and houses were thrown down, rocks were torn asunder, and the strongest works of art were injured or overthrown. A large slab, thirty feet thick, was rent from a cliff at the north end of the island of Lorenzo, and hurled into the sea. The piece was cracked nearly across, and the fissure was eighteen inches wide. An officer who commanded a ship then moored in the bay of Callao says that the water was in a state of disturbance, such as it would have had if boiling; the bubbles which covered the surface emitting an offensive smell; and the sea, before clear, became turbid, and dead fish floated on the surface. A chain cable of the vessel when drawn up presented a curious appearance, having evidently undergone partial fusion.

The violence of an earthquake seldom lasts

for more than a minute, but successive shocks may follow each other at short intervals. It is surprising how much mischief may be done in a few seconds, for during the agitation, short as it is, whole cities may be swallowed up, and large districts be converted into lakes or pools of water. The celebrated Kircher has left us an appalling description of the earthquake that, in 1638, swallowed Euphemia. "After some time," he says, "the violent paroxysm ceased. I stood up, and, turning my eyes to Euphemia, saw only a frightful black cloud. We waited till it passed away, when nothing but a dismal and putrid lake was to be seen where the city once stood."

There are countries where the agitation of the earth is so constant that the inhabitants almost become accustomed to it, and, as Humboldt states, bend themselves backward and forward to the undulations of the ground as sailors do to the tossing of a ship, caused by the motion of the waves. In countries where the shocks are only occasional the greatest fear is entertained, and the inhabitants become sensible of motions not felt by other persons. We have an instance of this mentioned in Captain Hall's Voyage to Chili and Peru. When paying an evening visit

to a family in Valparaiso, the whole party was suddenly thrown into great alarm, and rushed into the street, crying, Misericordia! Misericordia! The entire population was roused by the same fear, and the streets were filled with people in a state of wild confusion and alarm. The English traveller was quite unable to account for the distress on every countenance, but afterwards found that there had been an earthquake, though he was perfectly unconscious of the least motion.

That the reader may be able to form some idea of this terrible phenomenon, and of the effect it has upon those districts in which it happens, we will mention a few recorded instances.

In the year 1819 the western coast of India was visited by a severe earthquake, the effects of which were felt from Bombay to beyond the tropic of cancer. The centre of action seems to have been in the province of Kutch, which was more severely visited than any other part. The first shock was felt on the 16th of June, a few minutes before seven in the evening. There had been nothing peculiar in the atmosphere during the day to cause any apprehension of the evils that followed, but the wind, which had been blowing, suddenly fell just before the first

shock, and there was a dead calm. "The wretched inhabitants of Bhooj," says an eye-witness, "were seen flying in all directions, to escape from their falling habitations. A heavy appalling noise, the violent undulatory motion of the ground, the crash of the buildings, and the dismay and terror which appeared in every countenance, produced a sensation horrible beyond description. The shock lasted from two to three minutes, and during that short period the city of Bhooj was almost levelled with the ground, and 2000 persons perished in the ruins. The surviving inhabitants were obliged to forsake the city, and encamp outside of the walls, on some sand-hills. Their situation was truly distressing. Bruised, maimed, and in sorrow, they resorted daily to the city to extricate the mangled remains of wives, children, and relations."

Throughout the whole province of Kutch the destruction was very great, and many lives were lost. The fort-wall of Anjar, with its towers, were thrown down, and a writer says, "In one word, a flourishing population has been reduced in one moment to wretchedness and misery; and I fear we shall have to lament the loss of upwards of one hundred people, beside those hurt."

Ahmedabad, the capital of Guzerat, has been

long celebrated for its beautiful stone buildings, and especially for its shaking minarets, but the proud spire of the great mosque erected by Sultan Ahmed, built nearly half a century before, was brought to the ground. The greater part of the city was reduced to ruins.

In a letter written from Jelisheer we have the following particulars:—"The fort and town are reduced to ruins. Many of the people who are killed were out of doors, which is usually considered a situation of comparative safety. A marriage was about to be celebrated in a rich man's family, and the castes had assembled from various distant quarters; the shock occurred when they were feasting in the streets, and upwards of five hundred of the party were smothered in the ruins of the falling houses."

The British army was at this time on a plain situated between the fort and city of Bhooj, and the soldiers were affected by the heaving of the ground with the same sensation as is felt at sea by the rolling motion of the vessel. At Ahmedabad it was also felt, and one who witnessed the catastrophe at that place says the rocking was so great it was expected by all that the earth would open under their feet and swallow them. A native residing in Iseria gives

the following striking description of what he and others suffered during this violent paroxysm of nature. " Yesterday in the evening a noise issued from the earth like the beating of the *nobut*, and occasioned the trembling of all the people: it appeared most wonderful, and deprived us all of our senses, so that we could not see, every thing appearing dark before us; a dizziness came upon many people, so that they fell down."

In the British camp before Bhooj slight shocks, or perhaps we might with more propriety say vibrations, were daily felt for more than a month after the first earthquake. The rocking or rolling motion of the earth for some days produced in all who felt it a giddiness and slight sickness, accompanied with pain in the knees and an inclination to lie down rather than to sit or stand. A few days after the first shock a volcano about thirty miles from Bhooj opened, after which the agitation of the earth ceased, as was expected, and the inhabitants of Kutch were relieved from all their fears.

No great physical changes were produced by the earthquake at Kutch, although not a single town throughout the province escaped injury. At the moment when the violent shock was felt vast clouds of dust were seen ascending from the

summit of almost every hill and range of hills. Smoke also and flame burst forth at some places, and a native chieftain asserted that from a hill close to that on which his own fortress is built flames arose, and a large ball of fire was thrown into the air, and, falling upon the plain, continued to burn for some time. When the hill was examined on the following day, it was rent and shattered as if something within had sunk. In other places large masses of rock were separated, but the marks of strong convulsion were much less than were expected.

The rivers of Kutch are generally dry, except during the monsoon, but at the time of the earthquake they were suddenly filled to their banks, and continued so for a few minutes, when the water gradually subsided. One arm of the river Indus, which had been for years deserted on account of its shallowness, has been deepened by the earthquake, and has in some places eighteen feet of water.

A dreadful earthquake afflicted South America in 1812, destroyed the town of Caraccas, and, at almost the same instant, overwhelmed more than 20,000 persons in the province of Venezuela. Baron Humboldt, who had visited the city previous to its destruction, and afterwards took

great pains in collecting and arranging the descriptions of those who had witnessed the dreadful effects of this catastrophe, has given an interesting account in his personal narrative, from which the following facts have been obtained.

"The 25th of March was a remarkably hot day, the air was calm, and the sky unclouded. It being a festival day of the Romish church, a great part of the population was assembled in the places of worship. A few minutes after four in the afternoon the first shock was felt, and it was unusually severe, for it made the bells of the churches to toll, and the ground heaved like a boiling liquid. It lasted, however, for only about six seconds, and after the motion ceased the inhabitants thought the danger past; but a subterranean noise, like thunder, though much louder and of longer continuance, was afterwards heard. This noise was followed by other shocks, by which the town of Caraccas was entirely overthrown. The churches being at the time crowded with persons, many were crushed under their ruins; and altogether about ten thousand of the inhabitants were at once killed.

"Estimating at nine or ten thousand the number of the dead in the city of Caraccas, we

do not include those unhappy persons who, dangerously wounded, perished, several months after, for want of food and proper attention. The night of Holy Thursday presented the most distressing scene of desolation and sorrow. That thick cloud of dust which, rising above the ruins, darkened the sky like a fog, had settled on the ground. No shock was felt, and never was a night more calm or more serene. The moon, nearly full, illumined the rounded domes of the Silla, and the aspect of the sky formed a perfect contrast to that of the earth, covered with the dead, and heaped with ruins. Mothers were seen bearing in their arms their children, whom they hoped to recall to life. Desolate families wandered through the city, seeking a brother, a husband, a friend, of whose fate they were ignorant, and whom they believed to be lost in the crowd. The people pressed along the streets, which could no more be recognised but by long lines of ruins. • • •

"All the calamities experienced in the great catastrophes of Lisbon, Messina, Lima, and Rio Bamba, were renewed on the fatal day of the 26th of March, 1812. The wounded buried under the ruins implored by their cries the help of the passers by, and nearly two thousand were

dug out. Implements for digging and clearing away the ruins were entirely wanting; and the people were obliged to use their bare hands to disinter the living. The wounded as well as the sick, who had escaped from the hospitals, were laid on the banks of the small river Guayra. They found no shelter but the foliage of the trees. Beds, linen to dress their wounds, instruments of surgery, medicines, and objects of the most urgent necessity, were buried under the ruins. Everything, even food, was wanting during the first days. Water became alike scarce in the interior of the city. The commotion had rent the pipes of the fountains; the falling in of the earth had choked up the springs that supplied them; and it became necessary, in order to have water, to go down to' the river Guayra, which was remarkable swollen; and then vessels to convey the water were wanting.

"It being impossible to bury the dead, funeral piles were erected between the ruins, and the bodies were burned; in which duty the commissaries were engaged several days. Surrounded by the most appalling sights, separated from all the gay and festive scenes to which indulgence had been long granted, grieving over departed friends, and fearing that danger or death might

spring up at every step, conscience was roused, and the deluded people, thinking that the death which had overtaken their friends would soon close their own existence, vainly hoped to propitiate by unmeaning ceremonies and misdirected confessions the divine anger. Some, it is said, assembling in procession, sung funeral hymns; others, in a state of distraction, confessed themselves aloud in the streets. Children were found by parents by whom they had never till then been acknowledged; restitutions were promised by persons who had never been accused of fraud; and families who had long been enemies were drawn together by the tie of common calamity. If this feeling seemed to calm the passions of some, and open the heart to pity, it had a contrary effect on others, rendering them more rigid and inhuman.

"The town of Laguira and the surrounding villages were also entirely destroyed. From the 25th of March scarcely a day passed without a shock, until the eruption of Soufriere, on the 26th of April, during which period those who were saved waited with fear and trembling for the close of this awful visitation. 'On the fourth of April,' says an eye-witness, 'there was a very heavy shock, that made the vessels

tremble as if they had been on a reef of rocks; and from the "Independence" we could see the mountains move like a ship in a heavy sea, and large pieces rolling over them.'"

Many countries experienced alarming convulsions at the close of the year 1811 and commencement of 1812, the American continent especially. South Carolina, in the United States, which had not previously been disturbed by the awful circumstances attending the violent agents of nature, was then the scene of frequent and distressing hurricanes and earthquakes. A gentleman who resided in an island on the coast has recorded the events which occurred on the 10th of September. The island was deluged by an inundation of the sea, an occurrence frequent in tropical climates about the time of the autumnal equinox: the inhabitants were about to remove to Charlestown, when that city was visited by a dreadful tornado. The wind had been several days blowing with much violence, but about twelve o'clock on the 10th suddenly ceased. A heavy rumbling sound was then heard, and a tornado, extending in width about a hundred yards, flew through a considerable part of the city, involving alike the habitations and the inhabitants in instant destruction. Large houses

were not merely unroofed, but "completely overthrown like the playthings of an infant." Beams of wood, and masses of stone and iron, were carried several hundred yards, and some of them were even buried in the walls of other buildings. It is a singular circumstance, and one which shows how confined the action of the wind was, that parts of houses were taken off as if divided by some mechanical instrument, and the remainder of the building left uninjured.

In the interval between this calamity and the 16th of December, when the first shock of earthquake was felt, meteors of various kinds were frequently seen. One of these meteors was very large and brilliant, and was seen by persons a hundred miles distant from each other. "It illuminated," says an observer, "the ground and the surface of the waters as if a torch of burning matter had been passing over them, and was conjectured to have been about ten or fifteen feet in diameter."

The earthquakes commenced on the 16th of December, and continued occasionally till the 26th of March, the day after the destruction of Laguira and Caraccas. They happily passed without any destruction of property or personal injury; but the people, unaccustomed to such

dreadful phenomena, were greatly alarmed, and a seriousness of deportment was for a long time perceptible among the great body of the inhabitants.

On the 22nd of December, 1837, Mexico was visited with a very severe and destructive earthquake. The following particulars have been made known through the public press. The town of Acapulco is almost entirely destroyed, and the gorgeous city of Mexico tottered under the violent and prolonged shocks; happily however the latter place has received no injury. The details of the earthquake at Acapulco are very frightful. Repeated shocks of extreme violence nearly reduced the city to a mass of ruins. The houses were overturned and dashed to fragments, the churches thrown down, the walls of the Campo Santo irreparably injured, and the inhabitants, driven from their homes, were compelled to pass the night in the fields and roads near the town. When the morning dawned, hundreds beheld themselves houseless and reduced to utter indigence. Fortunately for the safety of the citizens the destruction occasioned by the periodical shocks was so gradual as to afford them an opportunity of escape.

It is a singular circumstance, and worthy of notice, that an earthquake felt at either of the places just named will also be experienced at the other. This fact has led many persons to the supposition that both Acapulco and Mexico are situated immediately over a vast chasm in which the internal heat is accumulated. Strange as it may appear, the spot where Mexico now stands was once a great volcanic centre, and in the immediate neighbourhood there are many extinguished craters. But, although these volcanoes are not now active, there is no security against their breaking forth at any moment; for many that have not been active for centuries have suddenly given warning of their renewed strength, and have devastated the surrounding country with the products of their eruption. No advantages of situation then could surely be a recompense to the Mexicans for the probability that at some future time their city may be overthrown by an earthquake or buried beneath a flood of lava; and what could have induced them to build a noble city in such a situation we cannot imagine. The country bears in many places strong evidence of the previous activity of volcanoes, and of the present existence of that internal force to which earthquakes may be

traced. Hot springs are not uncommon; and although these are not always evidences of great internal heat, yet, when they are found in countries where earthquakes are prevalent or volcanoes have before existed, there is some reason to believe that the agent producing them only slumbers.

A frightful earthquake desolated the island of Zante on the 29th of December, 1820. Some days before this happened the atmosphere seemed to be singularly disturbed, and presented a most remarkable appearance. On the day of the earthquake the clouds were arranged in groups, and were in a perpetual state of agitation; the lightning played without ceasing, and the wind from two o'clock in the morning blew so violently that it might be called a hurricane. About four o'clock in the morning the shocks were felt: eighty houses were instantly thrown down, and eight hundred greatly injured. "As if I foresaw," says a writer, "the misfortune that threatened us, I felt within me the most melancholy presentiments, and my mind was agitated with feelings that I cannot express. I threw myself on my bed, and was absorbed in the sullen and gloomy silence of nature, when all at once I was confounded by the most dread-

ful subterraneous roaring, which formed the commencement of our terrible catastrophe. The motion of the earth was felt: at that instant I rose immediately; but the violence of the shocks threw me back again on my bed. There were three shocks:—the first was very strong, and seemed as if the earth was heaving up; the second was a waving motion like the sea when agitated by a wind; and the third, which was most violent, produced a whirling motion. The earthquake continued for about thirty seconds; but, although so much injury was done to the town, only four lives were lost."

After the earthquake the island was exposed to violent storms of wind, hail, and rain. Some of the hailstones were two pounds in weight. A deluge of rain followed, and the streams, or rather torrents, flowing down the mountains which surrounded the town, not being able to find a passage in the canals, which were obstructed by ruins, carried away entire houses already shattered by the motion of the earth.

A few minutes before the earthquake a meteor was seen floating, as it were, on the sea, and burning brilliantly: it continued luminous for five or six minutes, and seemed to be about five feet in diameter. The day after the earth-

quake another meteor was seen moving in the air from east to west in a vast curve, and fell into the sea.

M. D'Aubuisson gives an admirable and comprehensive view of the influence of earthquakes. "They are," he says, "most frequent in the midst or in the neighbourhood of volcanoes; so that there is an intimate connexion between them, showing them to be, in all probability, effects of the same cause; namely, subterraneous fiery agents. The most common and best attested effects of earthquakes are cracks or crevices wrought in the mineral strata, when they experience a great concussion. When the concussions are sufficiently violent to fracture the vaults beneath, either premordial or formed by the conjunctions of the lavas, or to burst the pillars by which they are sustained, those mountains and soils fall back into the gulf from which they had arisen. It was thus that in the earthquake at Jamaica in 1692 the highest mountain of the island was swallowed up, and was replaced by a lake; that in Iceland a mountain of a considerable height was buried in one night by an earthquake, and its place occupied by a very deep lake; that, upon the 11th of August, 1772, the largest volcano of Java, the

circuit of whose base was upwards of twenty miles, suddenly sunk after a short and violent eruption, carrying down with it forty villages and two thousand inhabitants; that in 1638 the volcano of the peak, in the Molucca islands, which was visible at sea at a distance of thirty miles, and which commonly served as a beacon or light-house, totally disappeared in the middle of a violent eruption; and its place is filled by a lake at the present day. We are indebted to Baron Humboldt for the knowledge of many facts of the same nature. We have seen the Carguairazo, in 1698, crumble away, and overwhelm the neighbouring districts with its mud: and ancient tradition relates that the volcano of the *Altar de los Collanes*, in Peru, the height of which, it is said, surpassed that of the Chimborazo, sunk down after eight years of continual eruption; and its inclining eminences only exhibit at the present day traces of its destruction. In the soils occupied by extinct volcanoes we still perceive indications of sinkings or depressions, particularly lakes, which are presumed to be the ancient sites of craters or volcanic mountains: such are those of Laach, near the abbey of the same name, a few leagues from Andernacht; such also is the little lake,

perfectly circular, of Paven, in Auvergne. And, besides volcanic soils, we meet with many sorts of mountains, especially those which are of a calcareous or gypseous nature, which contain great caverns and cavities; and it is very natural to think that the concussions of earthquakes, when they are violent, may occasion the rupture and downfal of the masses which are above them."

As earthquakes and volcanoes have their origin in the same cause, and as the volcanic force was certainly active when the ancient rocks were in the process of formation, we may reasonably suppose that earthquakes had an influence in producing the present state of the earth's surface, and their effects may be frequently traced. We have not yet attempted to describe the various theories that have been proposed to account for volcanoes and earthquakes, nor shall we enter into this subject with any particularity. It will be sufficient to remark that, according to some geologists, the interior of the earth consists of pure metals, and that when water is brought into contact with them, it is decomposed; the oxygen uniting with the metal and forming an oxide, the hydrogen being liberated, and exerting all the terrible effects of a confined

and condensed vapour. Heat also is generated. The theory is no doubt sufficient to explain the effects, if the supposition can be allowed to have the slightest pretence to belief.

D'Aubuisson, an author from whom we have already quoted, after alluding to the situation of volcanoes in islands, or on coasts not far from the sea, comes to the conclusion that the vicinity of the sea is a condition essential to their existence, and that the water of the sea penetrating into their cavities is a cause of eruption. "We know," he says, "the astonishing power of this fluid when reduced to vapour or steam; but our steam-engines can scarcely convey to our minds an idea of the power which it is capable of acquiring in caverns whose sides are several thousand yards in thickness, and which sustain the mountains of Ætna and Chimborazo. Heat may extend its elasticity to a point of which it is difficult to form any idea." All theorists are, we believe, agreed in supposing that vapour is the agent by which the rocks are elevated and fissures are formed, but the cause of the great internal heat is differently explained.

CHAPTER VI.

THE STRATIFIED ROCKS.

As we have explained the elementary principles of the science of geology, and the nature and action of those agents by which rocks are produced, and the superficial form of the earth is modified, it will only be necessary to give a brief description of the mineral masses forming the crust of the earth, and the groups to which they belong, introducing at the same time a short description of the organic remains usually found in them.

ERRATIC BLOCK GROUP.

"We must impress upon the geological student," says Mr De la Beche, the author of the system generally followed in this work, "the necessity of considering this group as simply one of convenience, formed provisionally, for the purpose of presenting certain phenomena to his

attention, which, in the present state of the science, could not so easily be done under any other head. The origin of the various transported gravels, sands, blocks of rock, and other mineral substances, scattered over hills, plains, and on the bottoms of valleys, often referred to one epoch, may belong to several." It is true that some doubt has been expressed with regard to the periods when the diluvium beds were formed, and there is much difficulty in drawing a line between the beds supposed to belong to this group and those commonly associated with the supracretaceous series; but whether that difficulty warrants the doubts implied in the passage just quoted, may be a question of dispute. It is not our intention to enter the field of controversy, a spot of little interest to those who are only anxious to acquaint themselves with the principles of a science. We shall therefore chiefly confine our attention to a brief description of the organic remains which have been discovered in the varying deposits of the group, which some consider as an assumed and artificial classification, while others are confident of its propriety as a natural arrangement. Many of the organized creatures seen and described by our forefathers are now thought to be ex-

tinct, for they cannot be found in any part of the inhabited earth. The wide distribution of animals and vegetables, and their situation in particular localities, has been proved by naturalists; and every one is now aware that each country and district has inhabitants suited to its temperature and condition. On some parts of the earth's surface this may be more clearly observed than in others: thus, in Australia, for instance, a large number of the animals and vegetables are of a different class to any that are found in other countries. There are in that island, not only species, but genera, of a character altogether different from any discovered in other parts of the globe. If this island, or the part of it to which these animals are confined, had been by any violent catastrophe overwhelmed by the sea, the remains of these animals must have been deposited in some mineral mass, and would have presented us with the evidences of new races, and a state of country suited for their support. Such violent convulsions of nature have been common, and by them, in many instances, entire races of animals must have been destroyed. It is however singular, and a fact not yet accounted for by geology, that every series of beds has its peculiar fossils;

and by them a formation may be recognised, amid all the varieties of mineralogical character. There are, it is true, some shells and animal remains which may be found in many formations, but there are others which are discovered only in one; bringing us to the conclusion that whole species and genera have been entirely destroyed in the revolutions producing the deposits where they are embedded. In the following account of the fossiliferous groups we shall principally refer to the animal remains found only, or most abundantly, in them; and, in adopting this plan, our object is to explain the physical peculiarities of the earth at the periods when these rocks were produced.

The certainty with which the comparative anatomist may, from a few bones, or even fragments of bone, trace the forms and characters of the animals to which they belonged, is, perhaps, one of the most wonderful evidences of human ingenuity and skill. The progress that had been made in fossil osteology was, however, comparatively small, till the time of the illustrious Cuvier, to whom was reserved the task of deciphering these hieroglyphics of nature, and explaining the history of extinct animated beings. For this wonderful task he was admirably pre-

pared, by a profound knowledge of the osteology of existing species; and he soon astonished the world with the precision with which he combined the fragments that were placed before him, and described the animals to which they belonged. It is not our present object, nor would it be in place, to enter into a description of the facts upon which the science of comparative anatomy is founded, nor shall we in the following pages dwell on the anatomical peculiarities of the remains discovered in the several groups, but rather attempt to describe the animals, and ascertain the state of the earth when they lived on it.

The animal remains of the diluvian or erratic block group may be classed under two heads; those found in superficial gravels, and those buried in caves: the former belonged to herbivorous, and the latter to carnivorous animals.

THE MAMMOTH, OR FOSSIL ELEPHANT.

Many of the ancient writers have alluded to the discovery of bones in beds of gravel, and other superficial deposits. These were supposed to be the remains of an extinct race of man, a

supposition ridiculous enough when we compare the size of a man with that of an elephant, and yet in some degree justified by the remarkable resemblance between the bones; so strong that even an anatomist might be deceived. The prevalence of this opinion may also be accounted for by the tradition, existing among almost all nations, of a race of giants preceding the present human species. But when it was ascertained that the bones were those of an animal, naturalists considered them as the remains of creatures introduced by man into the countries where they had been found. The elephant was first brought into Europe by the Emperor Alexander, and was afterwards exhibited in the circus, at Rome. When Metellus defeated the Cathaginians in Sicily, he transported their elephants to Rome, on rafts; according to Pliny, one hundred and forty-two in number.

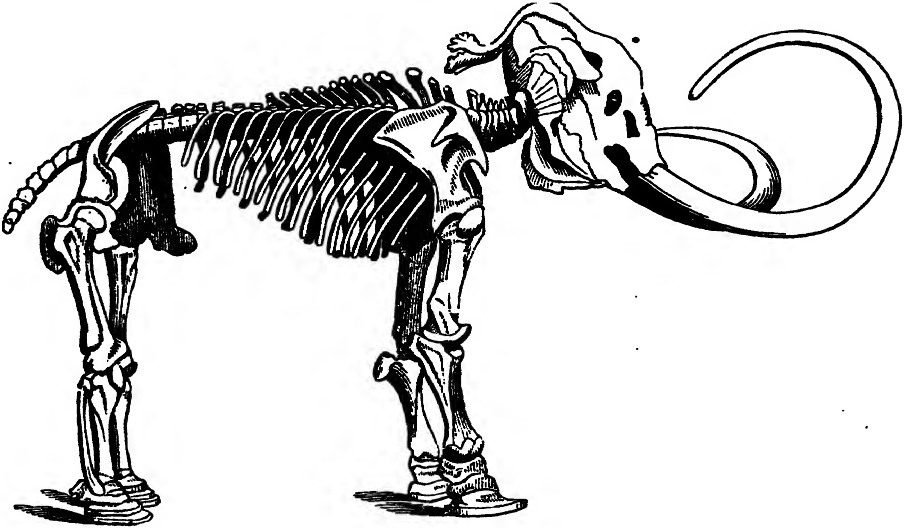
In many parts of Italy the bones of elephants are found, and in so great an abundance that the cabinets of natural history in Tuscany are said to be filled with them. In France, Spain, and especially Germany, as well as our own country, they have been obtained in great numbers, and often mingled with those of the

rhinoceros, and other animals. But it is unnecessary to enumerate localities, for we might fill pages with the names of places in Europe, Asia, and America.

That the relics of such an almost infinite number of these animals should be deposited in the detritus of all countries, almost from the pole to the equator, is a singular fact; but it is still more remarkable that the animal has been found, entire, preserved by the frosts of a polar clime. In the year 1799 a Tongoose fisherman observed near the mouth of the Lena a shapeless mass, the nature of which he could not determine, among numerous fragments of ice. On the following year it again attracted his attention, and was then more disengaged. On the fifth year it was thrown on a sand bank upon the coast, and an entire elephant was discovered. The fisherman possessed himself of the tusks, which he sold for fifty rubles. Nothing more would probably have been heard of the animal, but Mr. Adams, when travelling with Count Golovkin, was informed of the discovery, and determined to immediately visit the spot. The animal was found in a mutilated state, the body having been partly destroyed by wild beasts, and partly by the Yahoots, who had

cut away the flesh for their dogs. Still there was enough of the animal to exhibit its character. The skeleton was perfect, with the exception of a fore leg; and the principal bones were united with ligaments. The skin was covered with a reddish wool and long hairs, nearly thirty pounds of which were cut off and removed. It is still more singular, that the neck was furnished with a long mane. The head, without the tusks, which were nine feet long, weighed more than four hundred pounds. The skeleton of this animal is represented on the opposite page.

To trace the peculiarities in the anatomical structure of the fossil elephant, as compared with the modern species, would not be consistent with the plan of this work. It must have more resembled the Indian than the African species, and yet had less resemblance to it than the ass has to the horse. That its remains should be found so abundantly in polar climes, and countries where the modern elephant could not exist, must at first strike the attention; and yet when we are informed that it was covered with a thick wool and long hairs, we cease to feel any surprise; for there can be no doubt it existed in the places where its bones are now found, and that its

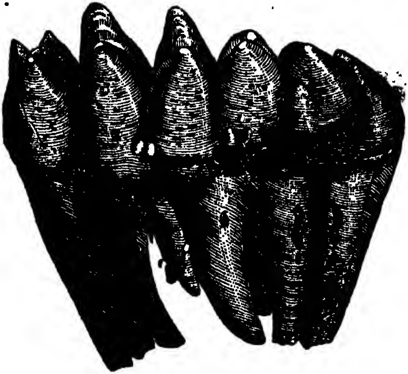


ARCTIC ELEPHANT.

habits of life were suited to a cold and even an arctic temperature.

THE MASTODON

is another extinct animal, whose remains have been found in the superficial gravel. They are most abundant in certain marshy tracts in North America, and for our knowledge of the osteology of the animal we are chiefly indebted to the specimens found there, and examined by various American gentlemen. Naturalists were far from decided as to the character of the animal



TEETH OF THE MASTODON.

when the bones were first discovered; but in the year 1801 Mr. Wilson Peale, the founder of the

Philadelphia Museum of Natural History, was informed that some bones had been dug up near Newburgh, on the river Hudson, and repaired there with his sons, and obtained a considerable portion of a skeleton. These bones, however, were not all that were required, and farther research was necessary. At last he succeeded in obtaining two almost perfect skeletons, making up what was wanting in the one by models from the other. The teeth of this animal are represented in the preceding figure.

There are several species of the mastodon. The great mastodon, or animal of the Ohio, in the museum at Philadelphia, is fifteen feet long, and eleven feet high. The following is Mr. Pidgeon's account of the animal:—"The great mastodon, or animal of the Ohio, was very similar to the elephant in the tusks and entire osteology, cheek teeth excepted. It most probably had a trunk; its height did not exceed that of the elephant, but its body was more elongated, the limbs thicker, and the belly not so voluminous. Notwithstanding these resemblances, the structure of the molars is sufficient to constitute it a different genus. It subsisted pretty much like the hippopotamus and wild boar, on roots and the stringy parts of vegetables. This

kind of food must have attracted it to marshy places, though it evidently was not formed for swimming or living in the water like the hippopotamus, but was decidedly a terrestrial animal. Its bones are much more common in North America than elsewhere."

Bones belonging to another species of mastodon, which, connecting the genus with the elephant, has been called *elephantoides*, were discovered by Mr. Craufurd, when on his mission to Ava. Descending the river Irawaddi, his steam-boat ran aground between Prome and Ava, near some petroleum wells; and on the shore masses of petrified wood and a vast quantity of bones were observed. Many of these were collected and brought to England; and in the second volume of the Geological Society's Transactions an interesting description of them by Dr. Buckland has been inserted.

THE HIPPOPOTAMUS AND OTHER ANIMALS.

With the remains of the fossil elephant have been found the bones and teeth of the hippopotamus, rhinoceros, horse, elk, ox, and other animals; of these a very short description will be sufficient.

Only one species of the hippopotamus is

known in the present day, but four species have been detected in the fossil state. One so nearly resembled the existing animal that it was at first thought to be the same; the second is about the size of the wild boar; the third is intermediate between these two; and the fourth was not larger than the guinea pig.

Many bones of the rhinoceros have been collected in various places; but in the year 1774 an animal was found in the frozen sand, near Vilhoui, with the flesh, skin, and hair remaining. With these remains are often associated those of the horse, a species smaller than that still existing; a gigantic ox, deer, and other animals. We cannot, however, enlarge on these, but must pass on to the consideration of one or two genera utterly extinct.

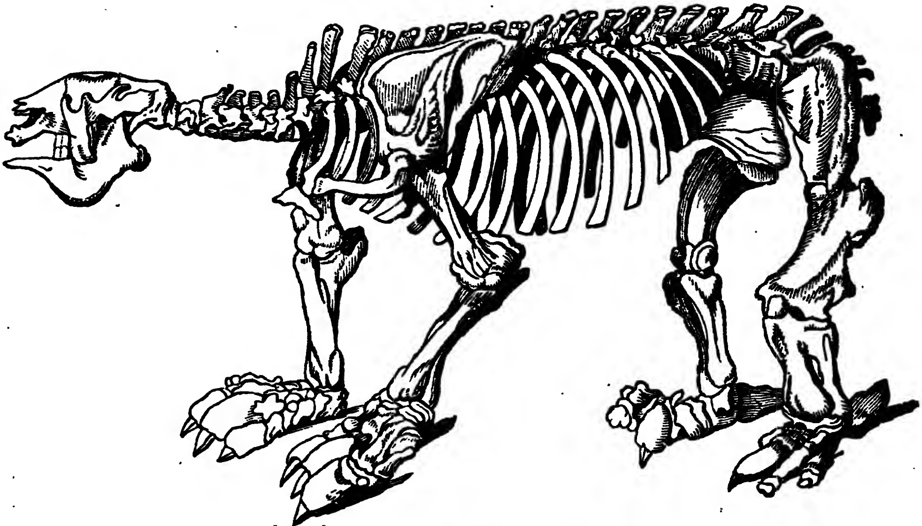
THE SIVATHERIUM.

Between the rivers Sutley and Ganges there are some sandstone hills, called the Sivalik, containing an immense number of fossil bones and teeth. Among these have been identified the mastodon, hippopotamus, rhinoceros, ox, elk, deer, monkey, camel, crocodile, various genera of fish, and fluviatile shells. For this interesting discovery we are indebted to Captain Cautley, of

the Bengal artillery, and Dr. Falconer. These gentlemen have also had the good fortune to find the skull and other parts of the skeleton of an animal before unknown, which they have called, from the locality, sivatherium. It was an animal larger than the rhinoceros, and had two pairs of horns, the front being small, and the hinder very large. It appears to have formed a connecting link between the two classes, ruminants and pachydermata.

THE MEGATHERIUM.

An entire skeleton of the megatherium was discovered some years since in a bed of clay, on the banks of the river Luxor, not far from Buenos Ayres, and was deposited in the museum at Madrid. This animal was not so large as many creatures now living on the earth, being only about seven feet high, and nine feet long; yet it well deserved the name that has been given to it, the great wild beast. The thigh bone is three times as large as that of the elephant, and the foot, which was furnished with claws, is about a yard in length. A representation of its skeleton is given in the annexed figure, and from that the reader may be able to form some idea of its unwieldy form.



THE MEGATHERIUM.

We might proceed to explain the anatomy of many other strange and extinct animals, whose bones have been discovered in the superficial gravel; but sufficient has been said to prove that the surface of the earth must have been recently, calculating time by geological periods, subject to violent floods which have swept away entire genera, and mingled their remains with the accumulated detritus. From this conclusion we cannot escape; the evidence is too strong to admit a doubt; but there are many questions arising from this statement that are not easily solved, and would lead to theoretical enquiries into which we cannot now enter.

OSSIFEROUS CAVERNS.

There are in various parts of this and other countries caverns in limestone rocks, containing the bones of animals. To Professor Buckland we are chiefly indebted for our knowledge of the circumstances under which these bones are found; for although the caverns of Germany had been previously examined, and collections made of their fossils, it was not till the discovery of the Kirkdale cave, in Yorkshire, that any precise information was obtained. The theory proposed

by Dr. Buckland has been warmly disputed by some writers, but all geologists award to this acute observer and eloquent writer the honour of having fairly brought the subject before the attention of scientific men.

The Kirkdale cave is situated in a compact bed of oolitic limestone. The original entrance to the cavern was very small, but by the removal of about thirty feet of rock in front the aperture became about three feet high, and five feet broad. The height of the cavern, proceeding inward, varied from two to fourteen feet. The roof and sides were partly covered with stalictites, being most abundant in those places were the cavern was intersected by vertical fissures. The floor was covered with mud and silt; and in this deposition were found pebbles, and the bones of the hyæna, tiger, bear, fox, weasel, elephant, rhinoceros, hippopotamus, horse, ox, and three species of deer; the hare, rabbit, water-rat, mouse, raven, pigeon, lark, and duck. Few of the bones were perfect, not that they had been destroyed by the atmospheric air, for they had been protected from this by the stalagmite with which they were covered, but had been apparently gnawed.

From the appearance of the cave, and of the

organic remains, Professor Buckland came to the conclusion that the cavern was, during a long succession of years, inhabited by hyænas, and that the animals whose bones are found were dragged into it by them. This theory, of course, admits that both the hyænas and other animals must have then been inhabiting the country where these remains are now obtained.

Among the most interesting ossiferous caverns of Germany may be mentioned the celebrated caves of Gaylenreuth. The entrance is in a perpendicular rock. It consists of a number of chambers, from fifteen to twenty feet high; and the floor is literally covered with the bones and teeth of animals. According to Cuvier, three fourths of the remains belonged to bears; but among others he discovered the bones of hyænas, tigers, wolves, foxes, and weasels.

Although much has been done toward an examination of the organic remains in limestone caves, we have but little information that can throw a light upon the formation of the caves themselves. The bones of the human species, and even rude fragments of early art, have been discovered with the remains of animals; and many persons have consequently come to the conclusion that man was in existence at the same

time as the animals. This, however, by no means follows; nor can we form any legitimate deduction from the fact until it is known whether all the creatures were destroyed by the same violent flood of water, or whether the carcasses have been brought in at different times, either by carnivorous animals inhabiting the caverns, or by floods. If the openings of these caves are filled up with detritus composed of the rocks in the vicinity, the latter supposition may be indulged; but if of fragments transported from a distance, we may be satisfied that they were contemporaneous, and destroyed at the same time by the same convulsion.

THE SUPRACRETACEOUS GROUP.

The super or supracretaceous group includes all that series of rocks formerly called tertiary. The strata which it includes are numerous and exceedingly interesting, although but little attention was paid to them until MM. Cuvier and Brongniart published the results of their examination of the country round Paris. Since that period geologists have, with much earnestness, directed their attention to these important deposits, and have examined with caution the

almost infinite variety of organic remains contained in them. But although much has been done we are not yet by any means fully acquainted with their superposition, that is to say, their relative ages, nor shall we be able to extend our information considerably until we can compare the deposits of distant countries.

Mr. Lyell has proposed a division of the supracretaceous group into four periods, founded on the per-centage of recent shells in the several beds. It has been some time past acknowledged by geologists that the fossils of modern beds have a greater resemblance to existing species than those which belong to more ancient rocks. This is peculiarly remarkable in the tertiary formations, and suggested to Mr. Lyell the idea of classifying them under four distinct periods. To do this with any degree of certainty it was necessary to study with great caution the organic remains, and to compare them with recent specimens. M. Deshayes, the most celebrated conchologist of the present day, undertook this task. In the oldest beds he found about three and a half per cent. of the fossils to be identical with recent species; in the beds above these, seventeen per cent.; in those still more modern, from

thirty-five to fifty per cent.; and in those which represent the most recent period, from ninety to ninety-five per cent.

The oldest of these periods has been called the eocene from ηως, the dawn, and καινος, recent; for its rocks give evidence of the commencement or dawn of the present conditions of animal life and form. To the second period the term miocene has been applied from μειον, less, and καινος, recent; and to the third and fourth the term pliocene, from πλειον, more, and καινος, recent, one being designated the older, and the other the newer.

Objections have been made to this classification under the supposition that it is impossible for any one conchologist to compare a vast number of recent and fossil shells, and to come to conclusions as to their resemblance or identity with which other conchologists will agree. We fully admit the difficulty; but to us it appears of far more importance to consider the present uncertain and changing state of the science of conchology, as well as the improbability that we have a collection of tertiary shells at all approaching to completeness. The judgment now delivered is therefore formed upon a most partial evidence. Still we are

of opinion that the division of the tertiary beds into four periods will be found convenient in research; and as our information increases the classification may be improved.

Since this paragraph was written Mr. Lyell has published his "Elements of Geology," in which he states that when M. Deshayes prepared the tables published in the "Principles" there were not more than five thousand species of recent shells in the Paris collections, but that now between eight and nine thousand are available in the public and private collections of Europe. The real value of Mr. Lyell's suggestion is, however, unimpared, although the exact per-centage of recent species in a fossil state cannot be determined; which is so far from being a matter of wonder that we are rather surprised at the unparalleled progress of tertiary geology during the last twelve years. Dr. Beck, however, has suggested a method of distinguishing the supracretaceous deposits, and of assigning their comparative ages without regard to the per-centage, a test which can never be applied until the deposit has been most fully investigated and all its fossils have been obtained. But when this has been done it will be most easy to compare it with any other supracreta-

ceous rock, and determine its precise comparative age.

"It has been suggested by Dr. Beck," says Mr. Lyell, "that in order to form such an estimate of the comparative resemblance of the faunas of different eras, we may follow the same plan as would enable us to appreciate the amount of agreement or discrepancy between the faunas now existing in two distinct geographical regions."

It is well known that although nearly all the species of mollusca inhabiting the temperate zones on each side of the equator are distinct, yet the whole assemblage of species in one of these zones bears a striking analogy to that in the other, and differs in a corresponding manner from the tropical and arctic faunas. But by what language can the zoologist express such points of agreement or disagreement, where the species are admitted to be distinct?

In such cases it is necessary to mark the relative abundance, in the two regions compared, of certain families, genera, and sections of genera; the entire absence of some of these, the comparative strength of others, this strength being represented by the numbers of species, sometimes by the great abundance and size of the

individuals of certain species. It is moreover important to estimate the total number of species inhabiting a given area, and also the average proportion of species to genera, as this differs materially according to climate. Thus, if we adopt comprehensive genera, like those of Lamarck, we shall find, according to Dr. Beck, that, upon an average, there are in arctic latitudes nearly as many genera as species; in the temperate regions, about three or four species to a genus; in the tropical, five or six species to a genus.

The method, of which the above sketch conveys but a faint outline, is the more easy of application to the tertiary deposits of Europe, because the conchological fauna of the eocene period indicates a tropical climate; that of the miocene strata, a climate bordering on the tropics; and that of the older and newer pliocene deposits, a climate much more approaching to, if not the same as, that of the seas in corresponding latitudes.

General Characters.—In taking a general view of the supracretaceous group we find that the deposits have for the most part an arenaceous character, though associated with clays, marls,

gypsum, and calcareous rock. Nearly all the deposits abound in fossils, some of which are of marine, some of freshwater, and some of terrestrial origin. Great difficulty has been felt by geologists in drawing the line of demarcation between the recent formations and the higher deposits of the supracretaceous group; nor are we by any means certain that the means now adopted have any claim to attention in the present state of our knowledge. With regard to the mineralogical characters of recent beds, and of the higher strata of the supracretaceous group, no distinction could probably be traced were the beds of the seas and oceans raised above the level of the water; and to distinguish, much more to discover, the points of difference between the organic remains, requires a naturalist of profound knowledge and extensive observation. We have already stated the difficulty of fixing the ages of the tertiary deposits by the character of their fossils, and it would be easy to prove, from observations that have been made, how closely the mineralogical structure of the recent and supracretaceous deposits would resemble each other.

NEWER PLIOCENE BEDS.

The only distinction between the newer pliocene and the recent strata is the presence, in the latter, of human remains and works of art. In every other respect they are the same. A few isolated deposits attributed to this period are found in England, but much more characteristic examples have been observed on the continent.

OLDER PLIOCENE STRATA.

To this period belongs a characteristic and interesting formation, called the crag. It consists of beds of sand and gravel, containing abundance of shells and corals, and has been divided into two sub-formations by Mr. R. C. Taylor, to whom we are indebted for the first, and by far the most important, investigation. The higher deposits may be described as a series of sand and gravel beds, having a ferruginous character, and containing but few organic remains; the lower are chiefly distinguished by being crowded with corals as well as shells. The crag was afterwards carefully examined by our late friend Mr.

Samuel Woodward, and more recently by Mr. Charlesworth, who designates the upper part of the formation as red, and the lower as coralline, crag.

In June, 1823, Mr. Taylor read a paper on the crag before the Geological Society of London, as observed by him at Bramerton, near Norwich, and in that communication he traces it over a considerable district.

"From Lowestoft to Bramerton," he says, "the crag shells are concealed beneath deposits of alluvial gravel, sand, and clay, of considerable but irregular thickness. To the east of Bramerton they have not, I believe, been recognised; to the west they may be observed at Whittingham, immediately in contact with the chalk; they may also be traced forming thin beds above the chalk on the opposite side of the Yare at Thorpe; and are not unfrequently met with several feet below the surface, on sinking wells in the city of Norwich. To the west of Norwich I have not hitherto discovered them, but to the north they may occasionally be observed at a few intermediate points between that city and Cromer. The valley of Wroxham, like that of Norwich, is sufficiently deep to intersect the crag, and to expose the chalk strata, which

here have attained a considerable elevation, and rise through the alluvial beds to a level with the surrounding country. At Cromer the crag passes into the sea immediately to the west of the jetty, and huge agglomerated beds of it may be observed scattered upon the beach at low water mark. From these masses the best specimens of shells may be collected. They consist chiefly of small mactra, probably mactra arcnata (Sow. Min. Con. pl. 71), and of turbo littoreus (Sow. Min. Con. pl. 81), mixed with fragments of mya lata, of cardia, and of balani."

Some years since, about the year 1830, we received a memoir illustrative of an outline map of the Suffolk crag district, by Mr. R. C. Taylor, for insertion in a scientific work, which, from several difficulties attending its publication, did not appear. The communication was one of great value, and, as it has never yet been printed, and as we have no means of communication with the author, we hope that we shall not err in presenting it now to the public with a copy of the map.

"This sketch (plate 6) exhibits, somewhat more in detail than heretofore, a tract which, although well known, is by no means undeserving of farther geological consideration. It comprises that series of sand and gravel beds which

occupies the south-east angle of Suffolk, and is remarkable for that extensive assemblage of marine productions which bear the local appellation of crag. The accompanying sections (fig. 1 and 2, pl. 6) are sketched to show the relative antiquity of this crag series, by defining the limits of the undisturbed London clay upon which it reposes, and the position of the overlying clays, which consist of materials transported from various anterior formations.

"Of the London clay little farther is necessary to be observed than that it probably terminates here. No proofs of its existence to the northward have been adduced. It is often partially concealed at the bottom of the estuaries by alluvium, but it unquestionably forms the base on which the ferruginous and sandy beds were deposited. The water which descends through these superior strata being intercepted by the London clay, that formation is often indicated by springs and by numerous small streams flowing from the base of the crag. At Felixstow cliff (fig. 2, pl. 6), the thin stony horizontal partings strongly remind us of the lias beds. Septaria are collected in great quantities from the banks which stretch in the sea for many miles opposite Walton Naze, Harwich,

and Felix. During the summer months the dredging and conveyance of this stone furnishes employment to a considerable fleet of small vessels. Before it was applied in a manufactured state to the purposes of cement, it was chiefly employed in the neighbouring country as a building material; amongst other instances, the ancient castle of Orford may be mentioned, as almost wholly constructed of septaria taken out of the sea.

"Respecting the upper deposits of loam and clay, usually called diluvial, which overlie the Suffolk sands, it may be sufficient to state they contain fragments of chalk, large and broken flints, boulders of various rocks, septaria or clay nodules, and other transported materials. Their most characteristic and abundant organic remains are large gryphites, belemnites, many species of ammonites, chiefly contained within the septaria, and vertebra of saurian animals, for the most part ichthyosauria. These clays cover the highest and most central portion of Suffolk, and extend northward into Norfolk. Their boundaries were correctly shown by Mr. Smith in his district maps, many years since. In Essex there are but few traces of this deposit, but it is worth remarking that, after

an interval of nearly sixty miles, it re-appears in a small patch, covering an area of not more than two or three square miles, between Highgate, Muswell Hill, and Finchley, from whence many specimens have been furnished to the cabinets of the Geological Society. It has here acquired its greatest elevation, which is, probably, double that of its ordinary height in Suffolk.

"The quality or structure of this derivative mass is various in many parts of its course through Suffolk and Norfolk. Perhaps it would offer some approach to a notion of its composition, were it stated that in the eastern side of Suffolk its prevalent fossils are those of the lias clay, mingled with those of the chalk; and with occasional indications of Kimmeridge clay. Along its western side, in both counties, it appears rather to have derived its origin from the debris of the green sand, the chalk, the lias, and probably the Orford clay. Traces of the stony oolites are rarely seen. Towards the north-east extremity, the clays contain substances of more early origin; fragments of trap, granite pebbles, and boulders of ancient rocks frequently occur in the excavations of the interior and in the clay cliffs, at least 250 feet above the sea.

" Recurring to the crag—for the present it

is sufficient to comprise within the following brief observations the conclusions to which a survey of the country under consideration seems to lead.

"These deposits are so associated that the whole obviously require to be classed under one common denomination. Nevertheless, to facilitate description, they may be arranged in two natural divisions. The first, or upper division, contains a numerous suite of beds of sand and gravel, more or less ferruginous, to which few, if any, organic remains properly belong. The lower division consists of beds which have no farther distinction than that of being crowded with an infinite profusion of very peculiar shells and zoophytes.

"The maximum elevation of the shelly beds is from 80 to 100 feet above the sea level; but their ordinary position does not much exceed half this height. In general they commence at a few feet above the present ocean; but near Aldborough there is reason to think some descend beneath the sea, from the circumstances of similar masses being constantly washed upon the beach during gales from the east. In a somewhat similar position they may be observed at low water, 60 or 70 miles farther north, near Cromer, resting upon chalk.

"Shelly crag extends but slightly south of the Stour, and only appears in small detached patches chiefly occupying the eminences of Walton Naze, Harwich, and Dedham. The first volume (second series) of the Transactions of the Geological Society contains a few details respecting similar deposits in Norfolk, and hence it appears that contemporaneous beds extend, with occasional interruption, across a space of about one hundred miles. In connection with this branch of this investigation it may be remarked that horizontal beds of ferruginous sand and gravel, much resembling in character the shell-less or upper portion of the crag, may be observed within thirty-five miles of the metropolis, on the high grounds of Essex, near Danbury Hill. In the absence of that useful and direct testimony which organic remains supply, it is impossible to pronounce upon the identity of these beds with the crag, and again with those of Hampstead, or with those yet more remote in the vicinity of Bagshot. We know very little of the fossils of that district, for they have never been figured or sufficiently described.

"It may be at once unhesitatingly affirmed here that there is no evidence to establish the identity between this great deposit of the eastern counties

and the so-called upper Marine formation in the Isle of Wight. Not a single species of shell is common to both; and in addition to this fact is another of no slight weight, that the marls of the Isle of Wight contain an abundant intermixture of fluviatile or lacustrine shells, from which the crag is wholly exempt.

"An accurate examination of the fossils of this rich depository seems necessary to determine the question of its comparative geological antiquity. About 130 species of crag shells have been named and figured by Mr. J. Sowerby. This catalogue is far from complete. Perhaps, there may be found 60 or 80 more species to be added to that list. No scientific investigation of its very peculiar and interesting series of zoophytes has even yet been commenced. The two species of echinites which it contains are at present undescribed; and the remains of its fishes, every where so abundant, have hitherto been neglected.

"There are few localities of the crag in which its shells have remained wholly uninjured by the tumultuous action of the waves. So far as the observation of the writer has extended, these shells seem to occur in a more comminuted state at their greatest distance from the present sea-shore. At Witnesham, at Dedham, and a few

other extreme points, the organic remains are seen broken into minute fragments; but nearer to the coast, and in the cliffs, perfect specimens may be obtained in abundance. Near Orford, Butley, Aldborough, and Haselwood, the regular distribution of genera, their deposition in their horizontal layers, the unbroken state of the corals and delicate zoophytes, placed in parallel beds, remind us of remoter formations, and announce that, here at least, they were deposited in comparatively tranquil seas, and that they have undergone but slight disturbance since the epoch of their existence. Often these fossils, the corals, the turbinolia, the retepora, the millepora, lobata and alcyonia, the sponges, the flustræ, and the escharæ, are seen in relief upon the calcareous slabs which the surf throws upon the beach, and even in those of the neighbouring excavations; and, when thus disposed, they strongly resemble the surfaces of recent coral reefs. Sometimes these tabular masses are composed of congeries of zoophytes and beds of flustræ, the substance of which, occupying the shells, exhibit casts as beautiful and as complete as are contained in any formation, whether tertiary or secondary.

" In the centre of the crag district are hori-

zontal beds of highly ferruginous sand or soft sand-stone, in which the shells solely occur in the form of casts. Below them are other beds where the shells do not occur as casts, and where the arrangement is at a considerable angle; an occurrence extremely common in other localities, and, in fact, one of the most prevailing features. These circumstances are introduced chiefly because it has been occasionally represented that the district now under notice consists of one irregular, unstratified mass of diluvium; differing in no other respect from diluvium in general than as containing marine shells; that it was not the production of an antecedent era, and, consequently was not entitled to geological distinction as a separate formation.

"With regard to the remains of terrestrial animals, they appear to have been drifted over the former surface, blended with its materials, and most frequently deposited along the margins of its estuaries. It does not appear that they occur in greater profusion or under different circumstances here than upon the banks of several other rivers, such as at the great bone depositories at Brentford, Ilford, and Gravesend.

"No instance has yet been authenticated of the occurrence of such animal bones within the hori-

zontal undisturbed and purely marine beds, like those near Orford and Aldborourgh; but they do occur in the higher disrupted and superficial deposits, particularly along the river banks and slopes of valleys; for the surface of the district which we have been considering bears the impress of diluvial action, scarcely less conclusive than that of far more ancient formations."

There are not, according to the general opinion of geologists, any strata in this country which belong to the miocene period; but there are some whose relative ages cannot be determined with any certainty, from the extreme fewness of their fossils.

EOCENE STRATA.

The lower tertiary formations, said to belong to the eocene period, may be best studied as a group of rocks in the Paris and London basins, and in the Isle of Wight; to each of these localities we shall briefly refer; but it will be well for the reader to bear in mind, as he follows our description, that the lower marine formation, which includes the London and plastic clay beds, is by far the most important in this country, being extensively developed in many districts.

Beds of the Paris Basin.

The highest formation of the series of beds found in the neighbourhood of Paris consists of freshwater marls, interstratified with beds of flint, containing the seed vessels of aquatic plants, as well as many animal and vegetable remains. Beneath these lie a series of marls and sand stones, abounding in marine shells, and collectively called the upper marine formation. Gypseous marls and limestones, containing bones of animals, and freshwater shells, are situated immediately beneath them. These deposits are also rich in organic remains belonging to animals of a higher class. Cuvier discovered many bones having a character resembling those of birds; and, after an extensive and difficult research, he succeeded in determining several genera, such as the pelican, curlew, woodcock, buzzard, owl, and quail. Bones of animals were also discovered.

The attention of Cuvier was first drawn to the animals found in the gypsum beds in the environs of Paris, by M. Vicarin, who presented him with a few specimens, which excited his curiosity. Having obtained access to many museums, his

mind was intently fixed upon the subject, and, having determined to commence the collection of specimens for the purpose of study, he ultimately succeeded in obtaining an immense number. To combine the fragments and to ascertain the characters of the animals, was now the object of his existence; and we may gather some notion of the enthusiasm with which he pursued his subject from the following passage: — "I cannot express my delight on finding how the application of one principle was instantly followed by the most triumphant results. The essential character of a tooth, and its relation to the skull being determined, immediately all the other elements of the fabric fell into their places; and the vertebræ, ribs, bones of the legs, thighs, and feet, seemed to arrange themselves without my bidding, and in precisely the manner which I had predicted!" The difficulties with which he had to contend were such as could only have been overcome by a mind unawed by doubt, and intently fixed on the object of pursuit. When he commenced the investigation he was satisfied that he should find many species, and he had not proceeded far before he ascertained that there was a difference of genera also. It is scarcely possible to realize the stupen-

dous difficulty of the task he undertook, without imagining the situation in which he was placed, when surrounded with the mutilated fragments of hundreds, and even thousands, of skeletons of various characters and sizes, belonging to different genera, species, and individuals, all of which were to be recombined, and to which, in his own expressive words, he was to give a lifeless resurrection.

The fossil quadrupeds found by Cuvier in the plaster quarries are classed under the two genera palæotherium and anoplotherium.

The Palæotherium. — The palæotherium, or ancient wild-beast, is allied to the tapir, which was for a long time considered as a hippopotamus. In Griffiths' Cuvier we find the following passage; — "The Malay Tapir," says Sir Stamford Raffles, "resembles in form the American, and has a similar flexible proboscis, six or eight inches in length. It's general appearance is heavy and massive, somewhat resembling the hog. The eyes are small, the ears roundish, and bordered with white. The skin is thick and firm, thinly covered with short hair. There is no mane on the back, as in the American species. The tail is short, and almost destitute of hair. The legs are short and stout." To this animal the palæotherium

bore some resemblance. Several species have been found in the environs of Paris, but, as Cuvier informs us, they do not differ in their teeth or number of toes, so that they can scarcely be characterised by any other method than their size. From the examination of specimens found in other places, some general characters have been distinguished; but we shall only mention one species, denominated the great palæotherium. This animal was as large as a horse, but more clumsy in its form. Its extremities were short, its head massive, and it was furnished with a short proboscis or trunk.

The Anoplotherium. — The anoplotherium, or unarmed wild beast, is one of the most singular animals met with among fossil remains, and there is nothing now existing analagous to it. It had two characters not observed in any other animal; feet, with two toes not united, as in the ruminantia, and a continued set of teeth without any intervening openings; such an arrangement, indeed, as had been previously only observed in man. The anoplotherium commune, so called, because its remains were most abundant, is supposed to have been about the size of a wild boar, but more elongated in form. It was probably furnished with a long

and thick tail, and swam well, like the otter, which animal it resembled in its proportions.

Bagshot Sands.

The sands which occur on Bagshot Heath and the surrounding country are supposed to belong to the same period as the upper marine beds of the Paris basin. They contain very few organic remains; indeed, after a long search, we have failed in discovering any in the parts we have examined. These beds can, therefore, have but little interest, except from the circumstance of their composing the heaths around the metropolis, and of their being the representatives of a remarkable geological period.

The Isle of Wight Beds.

The attention of scientific men was first drawn to the geology of the Isle of Wight by Sir Henry Englefield, who observed a range of chalk hills running from the east to the west of the island. In the summer of 1811, Mr. Webster was induced by this gentleman, "to examine the connection of the vertical strata with those on each side, which are horizontal,

and also the continuation of this range to the west on the opposite shore of Dorsetshire." The investigation thus commenced brought to notice an interesting series of beds above the chalk, to which we shall now direct the attention of the reader.

Alum Bay, a place of resort to all who visit the Isle of Wight, may be considered the most important section of the supracretaceous rocks in this country. Mr. Webster, in speaking of the strata at this and other places in the island, classifies his results under the following general heads, which comprise the several formations; and, in following his researches, we shall adopt the same arrangement; so the reader must bear in mind that the several formations are mentioned in an order the reverse of that generally adopted in this work, that is to say, the most ancient are first described.

1. The lowest marine formation, including the plastic clays and sand, and the London clay.
2. The lowest freshwater formation.
3. The upper marine formation.
4. The upper freshwater formation.

The Lowest Marine Formation. — The clay and sand cliffs of Alum Bay afford an interesting section of this formation. The va-

rious coloured vertical sands are too well known and too numerous to be particularly enumerated. To place Mr. Webster's observations as clearly as possible, and yet in a condensed form, before the reader, we will extract a few passages from his valuable memoir. The cliffs of Alum Bay "exhibit the actual state of the strata immediately over the chalk before any change took place in the position of the latter. For although the beds of which they are composed are quite vertical, yet, from the nature and variety of their composition, from the great variety and numerous alternations of the layers, no one who has viewed them with attention can doubt that they have suffered no change, except that of having been moved with the chalk from the horizontal to the vertical position.

"The north side of Alum Bay is bounded by a hill called Headen (fig. 2, pl. 3), about 400 feet high, considerably loftier than the vertical cliffs. In this hill only do we distinctly see the alternation I have mentioned, of marine and freshwater deposits. It is in a state of constant ruin, and, by its section, affords lofty vertical cliffs, where its strata may be examined with the utmost facility."

Lower Freshwater Formation. — This formation appears in Headen Hill as a series of sandy calcareous and argillaceous marls. Some of these appear to consist almost wholly of fragments of freshwater shells, though a few have been obtained sufficiently entire to determine the genera—they are lymneus, planorbis, and cyclostoma, and perhaps the helix.

"These beds are extremely irregular, and are not to be traced distinctly from each other for more than about a few hundred yards, the remaining part being so hid by the mouldering slope that the formation can only be observed in mass. It may be seen, however, extending round the north side of Headen into Fosland Bay, where it forms the upper part of the cliff: and at the point called Warden ledge it is found in a more uniform and indurated state. Here, when the clay upon which it rests gives way, from the rain and frost, large masses of it fall down, which are employed for the purposes of building, though the stone is not of a good quality. Pursuing it farther into Colwell Bay, it dips to the north and is soon lost: nor is it to be seen any more on that side of Yarmouth."

Upper Marine Formation. — A stratum of

clay and marl, containing a great number of marine shells, lies upon the lower freshwater formation in the Isle of Wight. It may be observed about half way up the cliff, at Headen Hill, and the shells are in some places so numerous they may be gathered by handsfull, and are exceedingly perfect. "Few of these shells agree with the species that have been found in the London clay, and they are also considerably different from them in their preservation, most of them appearing to have undergone but little change, and some are even scarcely to be distinguished from recent shells. The situation of this bed, distinctly placed above the vestiges of a freshwater lake, would seem to indicate some great revolution in the relative level of the land and sea, since the time of the marine deposit, which we have already considered; and the above circumstances, combined with its position as regards the vertical beds of Alum Bay, point out in strong characters a later period." In a fissure called Bramble's Chine, in Colwell Bay, a large bank of fossil oysters are found in this stratum. The formation may be seen at Cowes, Ryde, and Bembridge.

Upper Freshwater Formation. — At Headen

Hill, a thin bed of sand lies immediately above the formation just described, and on it rests a calcareous stratum, fifty-five feet in thickness, containing an abundance of freshwater shells, chiefly lymnei, planorbes, and helices. Upon this bed is a stratum of clay, eleven feet in thickness, containing numerous fragments of a small bivalve. "Upon this lies another bed of yellow clay, without shells, and then a stratum of friable calcareous sandstone, also without shells. To this sandstone succeed other calcareous strata, having a few freshwater shells."

Since the publication of Mr. Webster's memoir on the Isle of Wight beds, several other papers on the same subject have appeared; but, as little information has been added to that he communicated to the scientific world, we need not enumerate them. The sketch we have given contains the outline of the original observations; but the memoir itself must be referred to by those who wish to trace the relation between the deposits here spoken of and those discovered in other places, both in England and in France.

Hordwell Cliff. — We cannot close our re-

marks on the Isle of Wight beds without some allusion to the rocks at Hordwell Cliff (fig. 3, pl. 3), first brought to notice by Mr. Webster, in a memoir published in the Transactions of the Geological Society. Of this paper we shall endeavour to give an abstract. The portion of the coast of Hampshire here referred to extends from Hurst Castle to the village of Muddiford, a distance of about ten miles. The district is described in the following terms by Mr. Webster:—

"Where the bar of Hurst Castle joins the land, about half a mile south of the village of Milford, the shore rises into a low cliff, which for a quarter of a mile consists only of gravel; but at this spot the original strata appear, dipping a few degrees to the east. The cliff increases in height until it attains an elevation of about 200 feet, and continues nearly to Muddiford, without interruption, except where it is cut through by two streams that flow into the sea. The part properly called Hordwell Cliff extends from the spot where the original strata first appear at the eastward, just below Milford, to a place called Longmead End, a distance of a mile and a half. From Longmead End to a gap in the cliff occasioned by a stream called Beacon Bunny, is about half a mile, and

is called Beacon Cliff. Barton Cliff reaches about two miles and a quarter from Beacon Bunny to Chuton Bunny, where another stream, rather more considerable, comes down. The remaining portion, which extends to within a quarter of a mile of Muddiford, is called High Cliff."

The whole of the lower part of the Hordwell Cliff, according to Mr. Webster, consists of various alternations of clays and marls, containing freshwater shells, and, consequently, supposed to be a freshwater formation. Among others there are some beds of hard calcareous marl, probably derived from the trituration of shell of the genera lymneus and planorbis. In the lower part of the formation there are many fragments of lignite, and also a bed of the same substance a few inches thick. Below this formation at Hordwell, there is a bed of sand from sixty to one hundred feet thick. It "appears first about Longmead End, and may be well observed in the section at Beacon Bunny. This remarkable bed of sand forms one half of the heights of Barton Cliff, and is seen in the upper part of High Cliff, where it thins off, and terminates beneath the

A sandy clay, of a dark-green colour, and

considered identical with the London clay, lies beneath the sand. In the upper part of this bed may be found a great variety of fossils, and they may be conveniently obtained near Beacon Bunny. About the middle of the length of Chuton Bunny, a stratum of sand occurs beneath the clay, from which it is separated by a layer of rounded pebbles. The sand, which is of a dirty white colour, contains vegetable remains, and is identified by Mr. Webster with the plastic clay formation of the Isle of Wight, while the freshwater formation is supposed to correspond with the lower freshwater formation of the same locality.

A section of the Hordwell Cliff is given in pl. 3, from one by Mr. Lyell in the Geological Transactions, illustrative of a paper on the freshwater strata. The result of Mr. Lyell's inquiries we may state under four heads, as he has himself done:—

1. That no portion of the upper marine formation exists in this part of the Hampshire coast; for the uppermost beds of the Hordwell Cliff contain freshwater shells.

2. The freshwater formation extends to Barton Cliff, nearly opposite to Barton village.

3. "The fine white silicious sand of Beacon and Barton Cliffs must," says Mr. Lyell,—and the observation is so important, we give it in his own words,—"till some reason be shown to the contrary, be referred to the freshwater formation: but two beds of a similar white fine sand occur associated with the freshwater strata in Hordwell Cliff. It is therefore clear that, when this series was deposited, all the circumstances existed which were required for the formation of such sand; whereas nothing similar is found connected with the London clay in any part of England. The lower freshwater formation must thus be considered as extending throughout Barton Cliff, to about the middle of High Cliff."

4. The strata of Hordwell Cliff belong exclusively to the lower freshwater formation, and correspond with those between Yarmouth and Gurnet Point, on the opposite side of the Solent. The organic remains are, however, according to Mr. Lyell, of a mixed character, and this geologist consequently supposes the beds to have been produced in the estuary of a river within the influence of the tides.

London Clay Formation.

Immediately beneath the gypseous marls and limestones of the Paris beds, already described, is found a silicious limestone, with freshwater and terrestrial shells and plants; and a coarse rock, of the same character, abounding in marine shells. The latter is called the calcaire grossier, and is supposed to be analagous to that great argillaceous deposit upon which London stands, and called the London clay. This formation extends over a very considerable area, and is of various thicknesses. In the immediate vicinity of the metropolis it is a stiff blueish clay, but has a much darker colour in the Isle of Sheppey, where it is thoroughly impregnated with iron pyrites. It everywhere abounds with remains of marine animals, among which are not only found shells, but also fish, crustacea, turtles, and a species of crocodile. The fruits and seed vessels found in Sheppey are almost innumerable, and large pieces of wood are discovered at the same place.

Plastic Clay Formation.

Beneath the London clay, and resting immedi-

ately upon the chalk, some thick beds of sand and clay are found united under the general term of the plastic clay formation. The organic remains are of a mixed character, but, for the most part, in this country, are of marine origin; in the Paris basin they are chiefly freshwater and terrestrial. Near Reading, a layer of greenish sand, containing an immense quantity of oyster shells, rests upon the chalk; and at Bromley, in Kent, there is a calcareous deposit, with oysters and rolled flints. The beds of the London and plastic clay formations at Alum Bay, in the Isle of Wight, are in an almost vertical position, as shown in fig. 1, pl. 5.

From this general view of the supracretaceous group, it is evident that the agents still destroying and producing rock were, at the time of its formation, active in altering the outlines of districts and of countries. The relative levels of land and water were frequently changed. At one period the sea covered over an immense district, which, in process of time, was changed into a vast inland lake, the borders of which were inhabited by a race of animals now extinct. Another change passed over the countries we have examined, and a new state of things was

produced, by the advance of the sea, and the submersion of the lands before occupied by terrestrial creatures. By revolutions such as these, the rocks of the supracretaceous group were produced, not perhaps violently, in most instances, but by slow and progressive alterations in the physical conditions of countries. But the mind is most struck with the entire extinction of many races of creatures, strange and apparently almost monstrous in their forms, yet, without doubt, suited to the state of the earth at the period when they possessed it.

THE CRETACEOUS GROUP.

A series of rocks lying immediately below the tertiary deposits has been called the Cretaceous Group, from the circumstance that chalk is one of the most important members. It consists of two formations, the chalk and the green sand, to which may be added the Wealden rocks, until geologists agree in placing them under a distinct group, which ought certainly to be done.

The following table will give a general view of the beds composing the Cretaceous group, in the descending order.

Cretaceous Group.	1. Chalk Formation.	a. Upper chalk, soft and white, with numerous flints.
		b. Lower chalk, hard and a darker colour, containing but few flints.
		c. Chalk marl.
	2. Green Sand Formation	a. Upper green sand.
		b. Gault.
		c. Lower green sand and iron sand.
	Wealden Rocks.	a. Weald clay.
		b. Hastings sands.
		c. Purbeck beds.

Chalk has probably been seen in situ by nearly all our readers who reside near the metropolis, and in small masses by every body. Chalk is an almost pure carbonate of lime, and is usually white and soft, but in some situations it is found as a hard and compact limestone, and has, in many instances with which we are acquainted, been employed as a building material. The upper portion of the chalk is characterized by the presence of numerous nodules of flint, generally arranged in parallel seams, but in the lower part of the bed they almost entirely disappear; and on this account the formation has been divided into the upper, or chalk with flints, and the lower, or chalk without flints. In the southern countries it is generally white;

but in the north of England, and in several parts of the continent of Europe, it has a red colour.

The organic remains of the chalk are very numerous, and are decidedly of marine origin. From the softness of the bed, the fossils can easily be separated, and are exceedingly beautiful in appearance, and not less interesting as mementos of a geological period. Among them a few species of fuci are found, but the vegetable remains are not numerous. Teeth of the shark, and some other fish, may be procured in almost every chalk-pit; and some other beautiful ichthyological remains have been found both in Sussex and in Kent. We were many years accustomed to roam over an extensive chalk district, and from our own observation may state that, in Kent, the fish remains, excepting teeth and palatal bones, are confined to a few localities. The fossil shells are numerous and perfect; we may especially mention the terebratula, catillus, plagiostoma, belemnite, and pecten. Various species of the echinus, and some zoophytes, are also occasionally met with.

From the general appearance of chalk, and the character of the fossils contained in it, there can be little doubt that it was produced in the ocean, and is strictly a marine formation. There

is also reason to believe that it was deposited in a deep sea, and that a large number of the animals which existed at this period disappeared previous to the formation of the tertiary deposits.

The great area which is in England covered by the chalk formation may be traced by reference to the map at the commencement of this work. It extends from Flamborough Head to near Sidmouth, on the coast of Devonshire, and from this lofty range a branch is thrown off into the south of England. In the northern countries it is also extensively developed, as well as on many parts of the European continent.

There has been a difference of opinion among geologists as to the origin of chalk, and, among other theories, it has been maintained by some writers that it was produced by the decomposition of testaceous animals, corals, and echinæ. When we consider the extensive area which this rock covers, and its great thickness, frequently amounting to from 600 to 1000 feet, we do not wonder that the supposition was rejected by many eminent observers. The discovery, however, of a similar process going on in the present day, and producing an analogous rock, gives some evidence in its favour, and has led

many geologists to adopt the hypothesis. The origin of the flint in chalk is by no means decided; nor are we at all able to determine why it should have taken the form in which it is commonly found.

Chalk Marl is a bed of argillaceous and calcareous earth, usually soft, but in some places sufficiently hard to be employed for building purposes. It is the intermediate rock between the chalk and upper green sand, and frequently takes the characters of these two rocks at its junction with them. It may be studied with advantage at Folkestone or Reigate.

The Green Sand Formation may be said to consist of three divisions: the upper green sand, the gault, and the lower green sand, which rocks are admirably developed in the southern part of England. The green substance with which these sands are impregnated is said to consist chiefly of silex and protoxide of iron, with a small proportion of potash and alumina. The upper green sand seems in many places to graduate into the chalk, forming that rock which is called firestone. The gault is a blueish clay, and abounds with shells beautifully preserved. The lower green sand formation, which is an alternation of sand and sandstones with

clay, frequently contains beds of chert and fullers' earth.

The upper green sand is altogether absent from the series in the north of England, and is most fully developed in Wiltshire, though it may be well studied in Kent and Sussex. The lower green sand is wanting in Yorkshire, but is well exhibited in Lincolnshire.

Gault is known by various local names, from the places where it has been discovered; such as the Tetsworth, Folkestone, or Speeton clay.

The upper green sand formation frequently contains alternating beds of limestone, known under the local name of rag. Beds of clay and chert, with veins of chalcedony, are also common. The lower green sand consists of green and ferruginous sands, with intervening beds of limestone, clay, marl, and fullers' earth. The following is the usual position of the beds in the county of Kent, in the descending order:—

a. White, yellowish, or ferruginous sand, with concretions of limestone and chert.

b. Sand with green matter.

c. Calcareous stone, called Kentish rag.

Now, viewing the green sand formation as an entire series of rocks, we find that it is composed of a number of sand, sandstone, marl

clay, and limestone beds, containing a considerable number of fossils, all of which are of marine origin. Hence we are led to suppose that these beds were formed in the ocean, and by the disintegration of more ancient rocks; in the same manner as similar deposits are now forming in the present seas. After their production, a new physical condition was introduced, that which caused the quiet deposition or formation of the chalk in a clear, open, and, probably, deep sea. This alteration in the ancient seas is supposed to have been occasioned by the gradual submergence of the dry land, and an equally gradual change in the character of the deposit; so that the production of the cretaceous group, commencing with the lower green sand formation and terminating with the chalk, must have occupied a considerable geological period.

The cretaceous series of England has been much disturbed by the action of subterranean forces. In Plate V., Figure 1, we have a representation of the position of the rocks at Alum Bay, in the Isle of Wight, where the tertiary deposits are elevated, as well as the cretaceous, showing that the disturbance happened after the commencement of the supercretaceous period. In

Figure 1, of Plate IV., we have given a section of the rocks from Harrow on the Hill to Newhaven, which shows the elevation of all the formations of the cretaceous group, from the chalk to the iron sand, inclusive.

According to the observations of M. Elie de Beaumont, a violent disruption of strata immediately preceded the deposition of the cretaceous group. The evidence of this is found in the fact, that the chalk and quadersandstein, which is equivalent to our green sand, extend in a horizontal position over the inclined strata of the Erzebirge; which is supposed to have been elevated at a period between the formation of the oolitic and cretaceous groups. If we admit the truth of this deduction, it is not difficult to account for the production of the green sand formation; and by supposing a gradual submergence of the land, and the existence of a quiet ocean holding in solution the carbonate of lime, and under a high temperature, the origin of chalk may be in some measure accounted for.

But we have now another series of strata to explain, lying between the cretaceous and oolitic groups, and usually called

THE WEALDEN ROCKS.

The Wealden rocks may be divided into three formations; the Weald clay, the Hastings sands, and the Purbeck beds: all of which are of fresh-water origin. They are called the Wealden rocks, from the circumstance that they are best developed in the Wealds of Kent, Surrey, and Sussex.

The Weald Clay in Sussex is described by Mr. Martin, as "a stiff clay, brown on the surface, and blue and slaty beneath, containing concretional iron-stone." This iron-stone was once worked, but was not sufficiently rich to pay the proprietors. Beneath the weald clay there is a series of clays and sands, and a lime-stone, called the Petworth marble, remarkable for containing an immense number of the paludina vivipara. In the Isle of Wight, this formation consists of beds of slaty clay, limestone, and iron-stone.

The Hastings Beds. Mr. Webster says that, in the upper part of this series a grey sand-stone abounds; in the central part, a soft and yellow sandstone; and, in the lower, beds of clay, shale, and ferruginous sandstone. The Tilgate stone belongs to this series. It was in this rock

that Dr. Mantell discovered the remains of the iguanodon, an extinct and enormous reptile, allied to the iguanas, now found in some parts of America and the West Indies. A full-grown specimen was supposed to be, from the snout to the tip of the tail, seventy feet in length, and the body, about fourteen feet in circumference.

We may here introduce a few remarks on the remains of this period, by Dr. Mantell, which we believe have before appeared in a scientific journal. "In the fresh-water formation, comprising the beds between the oolite and the chalk, namely, the Purbeck, the Hastings strata, and the Tilgate grit, the remains of several reptiles occur abundantly; but those which are strictly marine, as the ichthyosaurus, are either altogether wanting, or of very rare occurrence. At the period of the formation of these deposits, turtles, both those which are marine, and those which inhabit fresh water, existed in great numbers, having as contemporaries, the megalosaurus, one or more species of plesiosaurus, several kinds of gavials and crocodiles, and, probably also, pterodactyles. At this epoch we have an enormous herbivorous reptile, which differed essentially from all other

oviparous quadrupeds, and surpassed in magnitude even the megalosaurus: this is the iguanodon, so named from its teeth resembling those of the iguana. A thigh bone, measuring twenty-three inches in circumference, and other bones of equally colossal dimensions, have been discovered: the teeth are as large as the incisors of the rhinoceros; and other parts of the skeleton bear the same relative proportions. This creature, like some of the recent iguanas, had warts or horns on its snout; and one has been found of the size and shape of the lesser horn of the rhinoceros. From the general character of the bones, it is supposed that the animal was shorter in proportion to its bulk than the recent lizards, to which it is most nearly related: but, even with this allowance, we cannot but infer, marvellous as it may appear, that it was fifty feet, or more, in length, and eight or nine feet in height. But a circumstance even more extraordinary than its magnitude, is the fact, that the iguanodon performed mastication like our herbivorous mammalia: its teeth, which are of a very peculiar form, being more or less worn by the operation of grinding its food. The vegetables associated with its remains, are all of a tropical character, and are allied to the dra-

gon-blood plants, euphorbia, &c. The strata in which they are entombed, unlike those of the oolite which preceded them, have been deposited in the bed of the river; while those of Stonesfield, which contain a somewhat similar association of fossils, have evidently been formed by a current which ran into the ocean of the oolite, and carried with it remains of terrestrial and fresh-water animals. The shells in the Stonesfield slate are marine, and similar to those of the other strata of the series; but those of the Hastings formation are decidedly fluviatile or lacustral."

The lower members of the Hastings beds are chiefly argillaceous limestones and schistose marls, and have been called the Ashburnham beds.

The Purbeck Beds consist chiefly of alternating strata of limestones and marls. The Purbeck stone is well known as a building material, and from its being employed in London for pavements.

Although we have now given such a description of the Wealden rocks as will enable the student to recognise their leading characters, and direct him to the places where they may be studied with most advantage; we cannot pass over this interesting and curious group of strata

without some general remarks. It has been already stated that the cretaceous rocks are decidedly of marine origin, and that the oolitic rocks, which will next demand our attention in the descending order, were also formed under the ocean, some change, therefore, must have occurred between these two periods to have permitted the formation of an extensive series of fresh-water beds. The shells of the Wealden rocks are almost exclusively those which are known to be fluviatile or lacustrine, such as the paludina, cyclas, and unio, and yet we occasionally meet with a bulla, an oyster, or some other shell of a marine animal. It becomes, therefore, a question of great interest to determine the probable cause and nature of the change which was produced after the deposition of the oolitic group. To ascertain this, we must examine the rocks which form the connection of the two series, that is to say, the lowest bed of the Wealden, and the highest of the oolitic.

In the island of Portland Mr. Webster observed a curious deposit called by the quarrymen "Black dirt," which divides the Purbeck beds, the lowest of the Wealden group, from the Portland, which is the highest of the oolitic,

or, in other words, separates the marine and fresh-water formations. This dirt bed, which is from twelve to eighteen inches thick, not only contains a large quantity of earthly lignite, but also the silicified trunks of coniferous trees, which are found sometimes in an erect position, to the height of three or four feet attached to their roots, and, by the union of broken pieces with them, a stem twenty or more feet in length has been completed. Hence there is every reason to believe that this ancient soil is presented to our notice in almost the same state as when it bore the tropical plants which, in their fossilized state, guide us to the knowledge of the operation of physical causes and the state of the earth at one of the most interesting geological periods.

From this evidence geologists are led to the conclusion that after the deposition of the highest bed of the oolitic series dry land appeared, and, in process of time, became covered with tropical plants, and, in fact, had all the characters of the most luxuriant forests of high temperatures. This state, however, was not of long duration, but the land being submerged the forest became a fresh-water lake, and was inhabited by appropriate animals. During this

period the Wealden rocks were formed, and then the sea again resumed its ancient dominion. This we have already attributed to the gradual submergence of the land, during which, the green sand formation was deposited, and, subsequently, the great calcareous mass called chalk.

THE OOLITIC GROUP.

Beneath the Wealden deposits is found an interesting series of rocks called the oolitic group, and so named on account of the peculiar structure of the limestones which form an important constituent part of the series. This group may be described in general terms as consisting of various alternations of clay, limestone, marl, and sandstone, which are better developed in this country than any other at present known to geologists. The mineralogical characters are not the same in all places, but the subdivision of the group into three natural parts, separated by thick beds of clay or marl, as suggested to those who first examined this series of rocks, is retained with but little alteration by the geologists of the present day. The following is the classification which has been found most convenient.

Upper Oolite.	Portland stone. Kimmeridge clay.
Middle Oolite.	Coral rag. Oxford clay.
Lower Oolite.	Cornbrash and forest marble. Great oolite. Fullers' earth, Inferior oolite.

To this series of rocks must be added another formation, called the lias, an argillo-calcareous deposit, crowded with the remains of saurians, belemnites, ammonites, and other animals which inhabited the ocean. This formation also is extensively developed in England, and from the abundance of fossils contained in it is of no ordinary interest to the geological collector.

It is worthy of remark that all these subdivisions rest upon clayey deposits which indeed form the separation between them. The upper oolitic system rests upon the Kimmeridge clay, the middle upon the Oxford clay, and the lower upon that vast argillo-calcareous mass called the lias. A general similarity is also observed in the other members of the three systems, so that it would appear as though a series of changes successively occurred in the physical world

during the lengthened period of their formation.

When the reader is informed of the number and variety of beds congregated together under the general term oolitic group, he can not be surprised that they vary, as observed at different places, in their super-position and general characters. It is scarcely possible to imagine that all the several deposits were formed over an immense area, with an unvarying uniformity, whether that area be imagined equal to the superficies of Europe, or the small and comparatively insignificant spot occupied by the British Isles. Our present information concerning the action of the agents of disturbance and recomposition forbids the supposition that any considerable series of deposits can have, throughout a large space, an identity of mineralogical characters, so that we are prepared for the discovery of varieties in the rocks produced at the same period, and differences of arrangement even in those extremely limited areas where the oolitic group is presented to our view.

Professor Phillips has given the following classification of the oolitic group in Yorkshire.

Kimmeridge clay.
Upper calcareous grit.
Oxford clay.
Kelloway rock.
Cornbrash limestone.
Upper sandstone, shale, and coal.
Ferruginous beds, or inferior oolite.

On the continent a general similarity in the arrangement of the members of the oolitic group has been observed, and they may severally be referred to particular rocks in the English series. Those who are at all acquainted with the examination of mineral masses will be prepared for the discovery of not only differences of appearance in the same mass, but of considerable changes in the characters and super-positions of systems of rock. The most important differences, however, in the oolitic group, are found in the lowest division, and these are so considerable when we compare the rocks of the south of England with those of Brora and Yorkshire, that it may be desirable at once to direct the attention of the reader to the fact.

The inferior oolite of Brora, on the south-eastern coast of Sutherlandshire, has been described by Mr. Murchison, and may be said to consist of three members.

1. Alternations of limestone with sandstones, shales, and ironstone, containing impressions of plants.

2. Ferruginous limestones with carbonized wood and shells.

3. Sandstone and shale alternating with beds of coal.

The coal deposit of Brora was of simultaneous formation with that in Yorkshire, described by Mr. Phillips as forming the intermediate bed between the cornbrash and inferior oolite. A similar series of beds is found in the Hebrides, and may be examined at Beal, near Portree, in the island of Sky. The oolitic series, including the lias, also appears in the island of Mull, of which a section is given in Figure 3 of Plate 4.

The plants discovered at Brora closely resemble those found in Yorkshire, and the shells are, for the most part, of the same species. In mineralogical characters, however, there is a considerable difference.

Professor Phillips has published, in his Treatise on Geology, an interesting table, giving a comparative view of the oolitic group in all its several formations in the north and south of England, by the examination of which, the

similarity and differences in these localities may be at once seen.

Peculiar to the North.	Common to both.	Peculiar to the South.
		Portland oolite.
		Sands.
	Kimmeridge clay.	
	Upper calcareous grit.	
	Coralline oolite.	
	Lower calcareous grit.	
	Oxford clay.	
	Kelloway rock.	
	Cornbrash & clays.	
Carbonaceous grit stone and shales.		Hinton sandstone and sands.
		Forest marble and clay.
	Great oolite.	
Carbonaceous grit-stone, shale, and coal.		Fullers' earth.
	Inferior oolite.	

To enter, with any degree of particularity or minuteness, into a description of the several formations comprising this important group would require a much greater space than can possibly be allowed in an elementary treatise. A few remarks, however, seem to be necessary for the purpose of guiding the student in his inquiries, or, we would rather say, in his examinations of nature. It is, perhaps, hardly possible to convey an accurate notion of the form, character, and peculiarities of rocks, by a description, to the mind of a person who has not some practical acquaintance with them from personal examination, whatever may be the accuracy with which it is written. The reader must not, therefore, expect to find that such an attempt has been made in these pages. The descriptions are of the most brief and general kind, but localities are mentioned in which the beds themselves may be viewed, and it cannot be doubted that more information will be derived from an examination of them, though but for a few minutes, than by a long continued study from books. Some of the most characteristic fossils are also occasionally mentioned, not that the mere names can convey any really valuable information, but because there

is now no difficulty, from the number of provincial institutions, in obtaining an opportunity of examining extensive and well arranged geological collections.

Portland Stone. — The series of beds composing the Portland stone formation, in the island from which it derives its name, is thus described by Mr. Webster.

Upper Beds.	Stonebrash, a cream-coloured limestone	3 feet
	Parting of the same with black clay . . .	1
	Cap-stone in three layers with partings of clay . .	10
Middle Beds.	Roach, a rock composed of fragments of oyster shells cemented together . . .	6
	White beds, marketable stone .	5
	Layers of flints and stony rubbish	6
	Middle bed, marketable stone, with few marine impressions .	5
	Parting stone with shells, of no value	2
	Third bed with few shells, generally the most saleable freestone	7 to 14
Lower Beds.	Many layers of flints, and of unserviceable stone . . .	50 to 60

A deposit of sand and marly sandstone was found beneath the Portland stone, and forming

a connecting link between it and the Kimmeridge clay, by Dr. Buckland and Mr. De la Beche. It has a thickness of nearly eighty feet, and is "co-extensive with the Portland stone throughout nearly the whole coast of Dorset, and is well exhibited by a vertical section near Black Nore on the west cliff of the Isle of Portland, and along the west shore from Black Nore to the village of Chesilton."

Kimmeridge Clay. — The Kimmeridge clay consists of beds of slaty clay, containing septaria. Bituminous shale is common. It is remarkable for its beds of ostrea delta. It may be studied with advantage in the Isle of Portland, and in several of the midland counties.

Coral Rag. — That formation called the Coral Rag consists of a series of beds, the upper ones being chiefly calcareous, and the lower silicious. The coral rag, which has given its name to the associated beds, is situated about the middle of the series, and is "a loose rubby limestone, mingled with, and often almost entirely made up of, a congeries of several species of aggregated and branching madrepores." A considerable number of shells are found, especially in the beds of calcareous grit.

The Oxford Clay is an immense deposit

of tenacious blue clay, and may be studied at Headington, two miles east of Oxford, where it is well developed.

Kelloway Rock.—That calcareous mass called the Kelloway rock, from its appearance at Kelloway Bridge, near Chippenham, in Wiltshire, contains many interesting and well-preserved fossils. It may be said to be the lowest member of the Oxford clay formation. "This limestone," says Mr. Conybeare, "is only used for mending the roads, and as there are very few excavations for this purpose, it is difficult to trace its course. Mr. Smith, however, mentions the following localities: Thames and Severn canal, near South Cerney; Kennett and Avon canal, near Trowbridge; Wilts and Bucks canal, near Chippenham; a pit, sunk in a fruitless search for coal, at Bruham, near Bruton, Somersetshire." This rock has also been identified by Mr. Phillips, as a member of the middle oolite of Yorkshire.

The beds which comprise the lower division of the oolitic system are far less constant in their arrangement than those which constitute the other portions of the group. The inferior oolite in Yorkshire, as already stated, differs essentially in character from that formation to

the south of the Humber. It abounds in fossil plants, vegetable matter, and coal. For a description of these deposits we must refer the reader to Mr. Lonsdale's recent and valuable paper in the Geological Society's Transactions, and Professor Phillips's Geology of Yorkshire. In the neighbourhood of Bath there are many opportunities of personal examination, and also on the coast of Yorkshire, especially near Scarborough.

Among the most interesting beds of this formation may be mentioned the Stonesfield slate, which is a shelly limestone, of an oolitic structure, and abounds in organic remains of the most interesting character. It lies, as shown by Mr. Lonsdale, beneath the inferior oolite. Among its fossils may be mentioned the impressions of ferns and other terrestrial plants, the wing-cases of some beetles, the remains of the plesiosaurus and pterodactyl, and the jaws of two mammifereus quadrupeds, allied to the didelphys or opossum.

From a general view of the oolitic group it is admitted, by all writers, that a long period of quietude was necessary for the formation of the rocks which compose it, and many arguments

may be drawn from the nature and peculiarities of the organic remains.

The corals are almost entirely confined to the limestone rocks; a fact which may be easily accounted for, as the animal which produced and inhabited the remains now found so abundantly, required a quiet and clear sea, and a supply of carbonate of lime. The coral rag has received its name from being almost composed of corals, frequently remaining in the position in which they grew. The extremely slow growth of coral is sufficient to prove that the rocks, of which it forms a large part, must have been produced in quiet seas, and by the lapse of long periods of time.

Belemnites also are common in many of the members of the oolitic series, and from their abundance, as well as from the frequent attachment of serpulæ, another argument has been drawn in favour of the slow deposition of the detritus which now forms the oolitic rocks. The belemnite is not the exterior covering of an animal, but an internal structure, similar to the bone of the cuttle fish; so that an interval must have transpired between the death of the animal and the period of its entombment: and an inter-

val sufficiently long for the destruction of the softer parts of the animal, and the growth of serpulæ upon the hard case.

LIAS.

That series of rocks which lies immediately beneath the oolites has been considered, by the majority of geological writers, to be a portion and the lowest member of the oolitic group. The entire formation has received the general designation of lias, a provincial term, which is now fully adopted by scientific men. In some localities the distinction between the oolitic deposits and the beds of the lias formation is very evident; while in others, as, for instance, in the neighbourhood of Bath, they are blended, or run one into the others. The lias may be said to consist of the five following subdivisions:—

The upper lias shale.
The marlstone beds.
The middle lias shale.
The lias limestone.
The lower lias shale.

This interesting formation may be studied to great advantage at Whitby, in Yorkshire, and is scarcely less strongly developed on the coast

of Dorsetshire, particularly in the neighbourhood of Lyme, where "it is displayed in a range of cliffs, extending about four miles, and sinking at length beneath a covering of the inferior oolite, and its sand." The lias rocks are of immense extent in this country, and cover a considerable area, so that the student may have many opportunities of examining them, and of obtaining some of the most characteristic fossils.

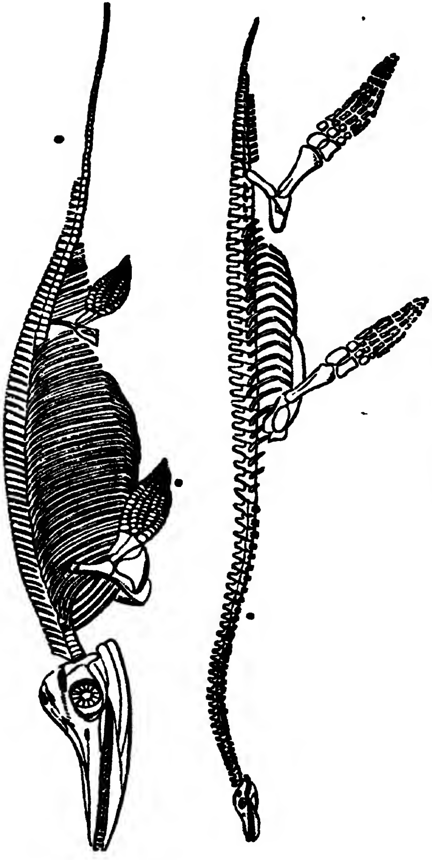
The lias is usually conformable to the beds of the oolite, but this is not always the case, as is well known in the instance near Lons-le-Saulnier, where the oolitic marls rest in a horizontal position upon lias, inclined at an angle of forty-five degrees. In some parts of Somersetshire it is much disturbed by faults, but the evidences of disturbance are local; so that even there it may be said to have a general horizontal stratification.

Among the fossils of the lias may be especially mentioned the gryphæa, which are so abundant that the rock is sometimes called the gryphite limestone. The ammonite, belemnite, and nautilus, are also peculiarly abundant. The ammonites are not only numerous as to specimens, but also in species; a great variety

having been discovered. Many indefatigable naturalists have been employed in the examination of the lias beds, and their efforts have been more than ordinarily successful, for no other bed of the group to which it belongs, perhaps excepting the Stonesfield slate, contains an equal variety.

The reptiles of the lias are peculiarly interesting; and, although not confined to this formation, were first found in it, and appear to have been more numerous during the period of its deposition than any other. We have, therefore, thought it desirable to introduce our descriptions of them in this place. The most important of these are the several species of ichthyosaurus and plesiosaurus.

The Ichthyosaurus.—To Sir Everard Home we are indebted for the first information concerning the peculiar characteristics of the ichthyosaurus. In the year 1814 he met with a part of the remains of this extinct animal, brought from some place between Lyme and Charmouth, and instantly recognised the relations to the crocodile. By the inquiries of Mr. Conybeare, and Mr. De la Beche, other specimens were obtained, and at last an entire skeleton was discovered.



THE PLESIOSAURUS.

The ichthyosaurus was an animal with four paddles like the cetacea, a sternum resembling a lizard, and a head like a crocodile. From its structure it is evident that it lived in the water, and, at one period in the history of our planet, must have existed in immense numbers. The remains are peculiarly abundant in England, and are found in various rocks, from the new red sandstone to the chalk. In some parts of the continent they are also found, but the greater number of remains are discovered in the lias of England. Some species attained an astonishing size. A specimen of the ichthyosaurus platyodon, now in the British Museum, and obtained from the lias at Lyme, must have been at least twenty-four feet in length.

When we consider the comparatively limited space for examination, and the immense number of specimens which have been discovered, it must be evident that the ichthyosauri were very numerous at that period when the lias was deposited. The existence of reptiles did not probably commence till after the deposition of the coal measures, and yet, when the lias beds were in the process of deposition, the earth, or at least certain localities of it, may be said to have absolutely teemed with oviparous quadrupeds,

which strangely disappeared before the production of the chalk.

The Plesiosaurus. — For the discovery of the plesiosaurus we are indebted to Mr. Conybeare. When examining some bones from the neighbourhood of Bristol, chiefly those of the ichthyosaurus, he detected some vertebræ which he was satisfied belonged to an animal of a different species.

The plesiosaurus differs from all other animals in the number of the cervical vertebræ. It had the neck of a serpent, attached to a body with proportions not much differing from those of a quadruped. Its tail was short, and, like the ichthyosaurus, it was furnished with four fins or paddles. The head was remarkably small, being less than one-thirteenth of the entire body, whereas, in the ichthyosaurus it was one-fourth. "Supposing these animals, therefore," says Mr. Pidgeon, in his account of fossil reptiles, "to have come in contact, a thing by no means improbable, as they inhabited the same waters, and from their conformation and analogies were evidently fierce and rapacious reptiles, the ichthyosaurus must have been an overmatch for its antagonist, unless the long and flexible neck of the latter gave it some ad-

vantages on the score of activity. The plesiosaurus, in its movements, and even, in some degree, in its figure, must have resembled the chelonian reptiles, or sea turtles." Mr. Conybeare is of opinion that it swam on or near the surface of the water, throwing back its head in the form of an arch like the swan, and plunging it into the water for fish as they came within its reach. But the plesiosaurus was not so well suited for swimming as the ichthyosaurus, and on the land must have been a very awkward creature. The gentleman to whom we have alluded as possessing the honour of discovery believes it to have chiefly frequented shallow waters near the coast, and probably seized its prey by stratagem, darting upon them from its hiding place among the weeds as they passed.

It was for a long time thought that all marine reptiles, analogous to those whose remains are found entombed in the strata forming the crust of the earth, had disappeared, but one has recently been observed in a foreign country, which is to the geologist a singularly interesting circumstance and must be here mentioned.

A curious marine reptile was discovered in the Galapagos island, during the visit of the

Beagle, in the year 1835, which is described with sufficient minuteness by Mr. Darwin. These islands it appears abound with reptiles of which there are two belonging to the family iguanidæ, of Bell, one terrestrial and one aquatic. "This marine saurian," says Mr. Darwin, "is extremely common on all the islands throughout the Archipelago. It lives exclusively on the rocky sea beaches, and I never saw one even ten yards in shore. The usual length is about a yard, but there are some even four feet long. It is of a dirty black colour, sluggish in its movements on land; but when in the water it swims with perfect ease and quickness by a serpentine movement of its body and flattened tail, the legs during this time being motionless, and closely collapsed on its sides. Their limbs and strong claws are admirably adapted for crawling over the rugged and fissured masses of lava which everywhere form the coast. In such situations a group of six or seven of these hideous reptiles may often times be seen on the black rocks, a few feet above the surf, basking in the sun with outstretched legs. Their stomachs, upon being opened, were found to be largely distended with minced sea weed, of a kind which grows

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at the bottom of the sea, at some little distance from the coast. To obtain this, the lizards are seen occasionally going out to sea in shoals. One of these animals was sunk in salt water, from the ship, with a heavy weight attached to it, and drawn up again after an hour; it was quite active and unharmed. It is not yet known by the inhabitants where this animal lays its eggs; a singular fact, considering its abundance."

From the time of the discovery of the remains of the ichthyosaurus and plesiosaurus, geologists have been speculating on the habits of these animals, and were led, by an examination of the remains, and the deposits in which they are found, to believe that they must have inhabited the sea, although no modern animal of the same character had been found in such a situation, previous to the discovery of the animal just mentioned.

From a study of the nature and position of the organic remains of the lias beds, there can be no doubt that they were formed in the ocean, and that the deposition of detritus must have been frequently sudden. The latter deduction is drawn from the fact that the remains of many of the saurians and fish are so found as to lead,

without doubt, to the conclusion that but a short interval could have occurred between the moment of their destruction and entombment. The skeletons of the ichthyosauri, for instance, are found with the contents of the stomach still within the animal, so that even the form of the excrement may be observed. Specimens of the sepia loligo, or pen and ink fish, also have been found with the ink in a dry state in the bags. Now, it is quite evident that had either of these animals been exposed for any length of time after death, and before they were enveloped by the mineral mass in which they are found, they would have become the prey of other animals, or the softer portions of the body would have undergone decomposition.

We may now close these general remarks on the oolitic group in the words of Mr. Lyell; a writer singularly happy in his generalizations. "If we now endeavour to restore, in imagination, the ancient condition of the European area at the period of the oolite and lias, we must conceive a sea in which the growth of coral reefs and shelly limestones, after proceeding without interruption for ages, was liable to be stopped suddenly by the deposition of clayey sediment. Then, again, the argillaceous mat-

ter, devoid of corals, was deposited for ages, and attained a thickness of hundreds of feet, until another period arrived, when the same space was again occupied by calcareous sand, or solid rocks of shell and coral, to be again succeeded by the recurrence of another period of argillaceous deposition."

THE NEW RED SANDSTONE GROUP.

The new red sandstone group, or that series of rocks lying beneath the oolitic deposits, may be divided into the following formations: —

Red or variegated marls.
Muschelkalk.
New red or variegated sandstone.
Magnesian limestone.
New red conglomerate.

Viewing these rocks as a group, they may be said to consist of red and blue marls, and red or variegated sandstones. Conglomerates, also, are not uncommon, of which class of rocks we have an example in Nottingham castle hill. The limestones of this system are well described by Professor Phillips: "They are often loaded with magnesia, and, in general, called magnesian limestone; but there are many beds in

which little or no foreign admixture deteriorates the carbonate of lime. The colours are white, grey, smoky, but more frequently yellow, and, in some districts, reddened or very red. In texture, a few limestones are compact, some oolitic, many cellular, the cell lined with crystallized carbonate of lime, a large proportion of a fine sandy grain, some quite powdery, with crystallized balls included; and, in Nottinghamshire, considerable tracts yield granular crystallized limestones. Near Sunderland, laminated rocks are really of sparry texture. Strings and plates of spar are very common, and render buildings of the magnesian limestone very irregular in their decay, from the unequal perishing of the stone between the ribs of spar."

The members of this group are admirably developed in the north of England. They may be said to extend in an almost uninterrupted series of strata from the Tees to the Exe.

Variegated Marls.

According to recent geological investigations, the variegated marls can scarcely be separated from the lias sandstones. In this country there

is no apparent passage of the lias into the red sandstone group; but Mr. De la Beche says that on the Wash, between Lyme Regis and Sidmouth, the upper portion of the series is so like the variegated marls of the continent, that he has little hesitation in considering them as contemporaneous deposits.

Muschelkalk.

The muschelkalk is generally a compact greyish limestone, and is sometimes sufficiently hard to be employed as a marble. On the continent many remains of reptiles and shells have been found in it, but in England the rock itself is absent from the series.

Red or Variegated Sandstone.

This formation is composed of silicious and argillaceous beds, differing much in colour, but chiefly of a reddish or blueish tinge. In some countries it affords a good building stone.

The Magnesian Limestone.

The magnesian limestone in England has generally a granular, sandy structure, a yellowish colour, and a bright lustre. In it are

found beds of gypsum and rock salt. According to Professor Sedgwick, it is equivalent to that deposit in Germany called zechstein, in which has been found the monitor, and a great variety of fish.

The Red Conglomerate.

The red conglomerate, which forms the lowest member of the red sandstone formation, consists chiefly of sandstones and conglomerates, generally of a red colour, and frequently containing angular fragments of older rocks. No organic remains have been found in it, and it is supposed to be identical with that series called by the Germans rothe todtliegendes.

Taking a general view of the whole series, we may speak of the group as being composed of a number of sandstones, marls, and conglomerates, with occasional beds of limestone, which are by no means constant in the localities where the series is found. In France the zechstein is absent, and in England the muschelkalk. The rocks are generally presented to view in a highly inclined and contorted form, from which it would appear that they have suffered much, both during and after their

formation, from violent volcanic causes, and to these we may trace the peculiar characters of some of the members of the group.

THE CARBONIFEROUS GROUP.

We have now come to the rocks which represent that important period when the coal beds were formed. Of all mineral substances none are so valuable to man as coal, and the clay ironstone with which it is associated. The carboniferous group, of which it is the superior member, may be conveniently subdivided into three parts—the coal measures, the millstone-grit and shale, and the carboniferous or mountain limestone.

Coal Measures.

The coal measures consist of a series of alternating beds of sandstone, shale, slate clay, and coal. In some of the coal basins the beds of coal are very numerous, being as many as forty or more in number. To give the reader an idea of the arrangement of these beds, we may enumerate the series passed through in some coal works at Rowley,

in South Staffordshire; where there are, including the soil, sixty-five beds of different substances intermixed without any apparent order.

Coal	11 beds	total thickness	81 ft.	7 in.
Limestone	1		30	0
Slate clay (shale)	30		715	8
Gravel	1		6	0
Bituminous shale	2		6	7
Sandstone	13		82	10
Shale	1		0	3
Clay	2		9	9
Ditto coaly	2		1	1
Ditto red	1		5	6
Soil	1		1	0
			940	3

Coal varies considerably in its qualities and in its adaptation for economical purposes, according to the quantity of bitumen it contains. All coal may be included in two classes,—the black or sea coal, and the cannel or candle coal, of which there are several varieties. The former is used in the metropolis and the south of England, and its mineralogical characters are a black colour and slaty structure: it sometimes contains thin layers of carbon, which causes it to soil the fingers when touched.

The shale or slate clay, called by the miners

shivers, and black metal, forms nearly three-fourths of the coal measures, and its strata are thicker than any of the others. It is a massive substance of a grey or blackish colour.

Next to the coal, the clay ironstone is the most important mineral in this formation, for it frequently yields as much as thirty per cent. of the metal after which it is named. At Merthyr Tydvil, in Wales, it occurs in continuous beds and layers of nodules, of which there are no less than sixteen. The quantity of iron obtained at this place in the year 1805 was 26,253 tons, since which time the works have been greatly increased, and now yield more than three times that quantity.

The vegetable remains of the shales, connected with the coal measures, are exceedingly numerous, and frequently well preserved. To enter into an examination of these, however, would lead us far beyond the limits which have been assigned to this work; and we must, therefore, merely state that there is every evidence, both in the character and situation of the beds, as well as in the chemical constitution of coal, of the vegetable formation of that important mineral. At a former period

some geologists maintained the mineral origin of coal, but all are now agreed in assigning it to the deposition of vegetable matter.

Millstone Grit and Shale.

The coal measures rest upon a series of rocks, called the millstone grit and shales. The millstone grit is a coarse grained sandstone, of much greater induration than that associated with the coal measures. It is evidently of a mechanical origin, and was, no doubt, produced from the debris of older rocks: it frequently contains felspar pebbles.

The shale is of a greyish or black colour, and alternates with the grit, though in the upper portion the grit prevails, and in the lower the shale. The organic remains are chiefly terrestrial plants, analogous to the coal measures.

Carboniferous or Mountain Limestone.

Beneath the millstone grit and shale is found a blueish grey compact limestone, frequently traversed by veins of calcareous spar; and from its associations with the coal series is called the carboniferous limestone. This rock is generally sufficiently hard and compact to

afford a marble susceptible of an excellent polish. In vegetable remains it is very rich, containing not only plants and shells, but some fossil fish, and a great abundance of encrinites, corals, and trilobites. This rock is found near Bristol, and in that locality contains so many encrinital columns that it is, in fact, almost formed of them. It may be studied to advantage in both the south and north of England, and in some places yields a large quantity of lead ore.

Figure 2, Plate 5, is a section of the carboniferous group, and associated beds between the Mendip Hills and Fog Hill, near Lansdown.

Figure 3, Plate 5, is a section of the same group, as it occurs between Pendle Hill and Holme Moss.

THE GRAUWACKE GROUP.

Geologists are by no means agreed as to the propriety of associating the old red sandstone with the carboniferous group, which we have just considered, although this has been generally done. But when we see the gradation

of the red sandstone into the grauwacke, we cannot doubt the propriety of classing it with that group, of which we consider it to form the superior member.

The old red sandstone is a formation distinguished from the rocks, both above and below it, by its fossils. It is of sufficient extent, and in all its characters distinct enough to be considered a separate group. Mr. Murchison states that in Herefordshire, Shropshire, and South Wales, it has probably a thickness of 10,000 feet, and consists of the following subdivisions:—

1. A quartzose conglomerate passing into chocolate, red and green sandstone, and marl.

2. Argillaceous marls, red and green, with irregular courses of impure concretionary limestone, provincially called cornstone. Remains of fish are found.

3. Finely laminated, micaceous, or quartzose sandstones, called tilestone. Several genera of molusca, and a few specimens of fish, have been discovered.

The grauwacke group consists of a number of slaty and arenacious rocks, with occasional masses of limestone. A slaty structure frequently prevails, and a substance fitted for

architectural purposes is sometimes obtained. A large portion of the series bears evident marks of a mechanical origin, the substance of which it is composed having probably been brought into its present position by rapid currents of water. Many organic remains are found in some of the beds. The productæ and spirifers abound, and also the family of the trilobites, which, in some parts of Wales, are so numerous that the slates are almost covered with them. Of the vegetable remains but little is known, nor can we form any precise notion, from them, of the vegetation of the earth at the period of their deposition.

LOWER FOSSILIFEROUS GROUP.

Concerning the rocks forming the lower fossiliferous group but little can be said: we shall merely quote the remarks of Mr. De la Beche, the geologist to whom we are indebted for the arrangement we have followed:—

"This group should be considered as little more than one of convenience, in which rocks, containing a few organic remains are sometimes mixed with strata of the same character

as those enumerated under the head of non-fossiliferous rocks; so that we seem to have arrived, in the descending order, at a state of the world when there was a combination of those causes which have produced fossiliferous and non-fossiliferous strata. That there should be a transition or passage, even effected by the alternate operation of particular causes, from that condition of the world's surface when chemical action prevailed to that when mechanical action became more abundant, is what we should expect, since it is in accordance with our knowledge of rock deposits generally; for we observe, however sudden changes may have been produced in particular situations, that, viewed on the large scale, a general change of circumstances attending rock formations has been more or less gradual."

Professor Sedgwick and Mr. Murchison have recently been engaged in the investigation of the rocks lying immediately below the old red sandstone, and have added much valuable information to our knowledge of these interesting deposits in England and Wales. By these gentlemen they are classified under two groups, which are severally called the Silurian and Cambrian. The Silurian, which is the group

of most recent formation, has been so called because the beds of which it consists are best studied in those parts of England and Wales which were once occupied by the Silures.

Mr. Murchison proposes to divide the Silurian group into four separate formations, which are severally denominated the Ludlow, Wenlock, Caradoc, and Llandeilo, from the names of the places where the formations are best developed. The two former of these are said to constitute the upper Silurian system, and the others the lower. The following table will convey to the reader, at a glance, the result of Mr. Murchison's investigations, and will at the same time explain his system of classification.

	Formation	*Thickness.*	*Subdivision.*	*Mineralogical Characters.*
Upper Silurian.	Ludlow formation..	2000	Upper Ludlow rock	Slightly micaceous, grey coloured, thin bedded sandstone
			Aymestry limestone	Subcrystalline grey or blue argillaceous limestone
			Lower Ludlow rock	Sandy, liver and dark coloured shale and flag, with concretions of earthy limestone
	Wenlock formation..	1800	Wenlock limestone	Highly concretionary subcrystalline grey and blue limestone
			Wenlock shale	Argillaceous shale, liver and dark grey coloured, rarely micaceous, with nodules of earthy limestone
Lower Silurian.	Caradoc formation..	2500	Flag	Thin bedded, impure, shelly limestone, and finely laminated, slightly micaceous, greenish sandstone
			Sandstones, grits, and limestones	Thick bedded, red, purple, green and white freestones; conglomeritic quartzose grits, sandy and gritty limestones
	Llandeilo formation..	1200		Dark coloured flags, mostly calcareous, with some sandstone and schist

In the rocks of the Silurian group many fossils have been discovered, such as fuci, corals, serpula, mollusca, trilobites, and sauroid fish.

The Cambrian group, so called because well developed in North Wales, has but few fossils. The following is a table showing the superposition of its several members.

1. Grauwacke and grauwacke slate. Hongill. Kentmere. Plynlymmon.
2. Dark argillaceous limestone, sometimes associated with slate, and containing fossil shells and corals. Coniston. Bala limestone.
3. Slaty rocks, sometimes associated with grauwacke and conglomerate. Langdale. Borrowdale. Snowdon.
4. Lowest slaty group. Skiddaw.

We have now brought before the attention of our readers a general view of the characters, fossils, and superposition, of the aqueous rocks, and such an one, it is hoped, as will induce the reader to investigate for himself. How inadequate any such brief outline must be to give a knowledge of the science, we are not ignorant; but, if we have succeeded in teaching the alphabet of the science, our object has been so far accomplished.

CHAPTER VII.

INFERIOR STRATIFIED AND NON-STRATIFIED ROCKS.

In the classification adopted in this work the rocks formerly known as primitives are divided into two groups, one called the inferior stratified, and the other the non-stratified. This arrangement has been disputed by some geologists, for it is doubted whether any of the non-fossiliferous rocks, having a crystalline structure, can, with propriety, be called stratified. The gneiss is a laminated, and, as some persons say, a stratified mass; but those who deny the stratification of this rock urge that it frequently passes into granite, and that the two rocks cannot therefore be separated. Into this question we need not enter in an introductory work;—it will be a sufficient reason for the adoption of our present plan, that it facilitates the progress of the young geologist, and enables him to commence, with more ease, the investigation of these singular, irregularly disposed, and frequently

enigmatical masses. The observer will find a difficulty in distinguishing between the varieties of some of the rocks, and still more in tracing their connection and arrangement. But, before we proceed to describe the respective masses, it may be desirable to make a few remarks on crystalline rocks generally.

Those stratified beds which have a crystalline character were not produced by mechanical agents alone, or, at least, such is the opinion formed by geologists, with their present knowledge of physical agents. It was once supposed that a bed formed by deposition could not under any circumstances take a crystalline character, but how far the appearance of a deposit may be changed by the action of electric currents cannot at present be told, though the few experiments which have been made are sufficient to prove that they have had an immense influence in the arrangement of mineral substances. The crystalline rocks, however, have no doubt been produced by chemical agents, and it is a question of great interest to determine the manner in which they were formed; but this is found to be an exceedingly difficult task. There are two ways in which crystalline compounds may have been produced—by deposi-

tion and by fusion: the greater number are evidently attributable to the latter. Thus, granite, for instance, cannot have been formed by a sedimentary process; the separate existence of three or more minerals in a crystalline state, and united so as to form a mass, could only have resulted from the action of heat. Crystallized carbonate of lime, on the other hand, may have been a deposition from an aqueous solution, or it may have been formed by the subsequent fusion of a calcareous bed under the pressure of superincumbent rocks.

To determine whether a rock has been crystallized immediately after its deposition, or by the action of heat—that is to say, whether the rock is attributable to aqueous or igneous causes—the following particulars must be observed. When a crystalline stratified bed is found among those of evident mechanical formation, and the series presents no appearance calculated to give reason for the supposition of a violent disturbance, the observer may conclude that the crystalline character of the rock was caused by aqueous chemical deposition. But, if it be near to igneous rocks, or if the rocks with which it is associated have such an appearance as leads the geologist

to suppose they have been disturbed or acted on by igneous causes, he may attribute the present structure of the rock to the chemical agency of heat. It has been stated by some writers that many of the rocks now having a crystalline structure were formed by deposition, and have since received a new character in consequence of the heat to which they have been subjected; while others still maintain that they formed a part of the primitive earth, and have suffered no other change than that of elevation and intrusion among the more recent formations. Into this question we shall not enter.

SIMPLE MINERALS FORMING ROCKS.

To understand the nature and distinguish between the characters of those mineral masses called primary or primitive, which we have called the inferior, it is necessary that some information should be obtained concerning the simple minerals that compose them. The elementary mineral substances are but few in number, yet it is evident that, by their union in different proportions, they may form an almost infinite number of substances, dif-

fering from each other in colour, structure, and all external characters. Nothing is more common than the disappearance of one rock and the appearance of another; or, in other words, the blending of one with another.

The four earths, silex, alumina, lime, and magnesia, with the metal iron, are said to form nineteen parts out of twenty of the mineral substance of the globe. The alkalies, potash and soda; the metal, manganese; with carbon and sulphur, are almost the only other ingredients entering into the composition of rocks; yet no task is, perhaps, more difficult than that of giving names to the various mineral masses, and of distinguishing one from another. Some of the simple minerals we have attempted to explain, but it is not necessary to describe those elementary substances which are supposed to be generally known; such as silex, alumina, lime, and iron. We shall only make one remark in reference to magnesia.

All those rocks in which magnesia appears as a component part, and in any abundance, have a soapy feel, and generally a striped appearance.

Felspar.—That mineral called felspar * is

abundant among the primitive rocks. It is an important ingredient in granite and porphyry, and also appears as an independent mass. It varies greatly in colour, but is usually of a white, grey, yellowish, or reddish white colour. When crystallized it is translucent: in structure it is laminar. When melted, which may be done without the addition of an alkali, it will form a glass, the transparency of which will be greater or less, according to the ingredients (found to vary considerably in different specimens) that compose it. In some granites it is a very abundant component part, and is well known to be liable to rapid decomposition when exposed to the atmosphere, which may be attributed to the presence of potash. According to the analysis of one specimen of this mineral, it consists of — silex, 63 parts; alumina, 17; potash, 13; lime, 3; oxide of iron, 1; three parts in the hundred being given for loss. In some of the felspar rocks soda has been found to occupy the place of the potash, giving a slight alteration to the crystalline form of the mineral; this variety has been called cleavelandite.

Hornblende. — That substance called horn-

blende by English mineralogists, and amphibole by the French, is extensively distributed among the primitive rocks, and, as stated by an eminent geologist, appears to connect them with those of volcanic origin. Few minerals have more distinct and easily distinguished characters. It is commonly of a dark green or black colour; yields to the knife, which leaves a light green scratch; melts by heat into a black glass, and yields, if we may so speak, a bitter smell when breathed on. According to analysis it is composed of—silex, 42; oxide of lime, 23; magnesia, 16; lime, 9; alumina, 8; and manganese, 1. This substance is one of the two component ingredients in the composition of basalt, and what are called the trap rocks.

Mica, a substance deriving its name from the Latin word *micans*, glittering, is of a laminated structure, the plates having a white, yellowish brown, or blackish green colour. It melts into an enamel under the blow-pipe, and its surface yields to the knife. In appearance the mica and talc so closely resemble each other that the geologist is sometimes unable to distinguish them by their external characters; but the elastic property of the

mica is sufficient to decide the question. Talc is flexible, infusible, softer than mica, and has a soapy feel. In mineral masses it frequently passes, by insensible gradation, into chlorite; "and in this state," says Mr. Bakewell, "it supplies the place of mica in most of the granite rocks that I have examined in the vicinity of Mont Blanc." The same author has given the following list of the constituents of these three minerals:

	Mica.	Talc.	Chlorite.
Silex	50	62	41
Alumina	35	2	6
Lime	1		1
Magnesia	2	27	40
Oxide of Iron	6	3	10
Water and loss	6	6	2

These analyses are in some respects useful, but it must be remembered that the proportions will vary greatly in different specimens. It is for this reason that one rock will frequently run into another, the proportions increasing or diminishing, until one character is lost and another is gained. But if there be such changes in the character of the simple minerals we may be prepared for still greater in those masses where they form component parts. Such is found to be the fact, for rocks do not often retain for

any great distance the same character; and it is almost impossible to give a name to many of the hand specimens which may be placed before us.

THE INFERIOR STRATIFIED ROCKS.

Hitherto our attention has been confined to those rocks in which the remains of organized beings are found; but we have now arrived at a class altogether destitute of them, and consequently supposed to have been produced before their creation. A world without an inhabitant is a gloomy imagination, and a person unacquainted with the science of geology might consider it equally dreary to examine the rocks which represent the period. All those who have any information concerning the arrangement and character of these masses; all who have speculated on their origin, and traced them through the constantly varying appearances they present, must have formed a different opinion. The same scene does not equally, or even similarly, affect all those who view it; partly, perhaps, because habit gives a tendency to our predilections, but chiefly because the constitution of mind is as marked as the physical characteristics

of external nature. There are some persons who delight in lowlands, richly cultivated, and covered with the green of summer, or the yellow hue of harvest; there are others who are best pleased with the bold, rugged, precipitous, and even terrific scenery of the highlands; and feel a glow of enthusiasm as they wander over the barren sides and snow-capped pinnacles of mountains. But, without recalling to our recollection the impressions produced on our mind by what some calculating persons would call dreary, desolate, and unprofitable regions, we may state that all scientific men are agreed in the assertion that no branch of geology offers more interesting subjects of investigation than the one we are now about to consider.

"It must, however," as Mr. De la Beche has said, "be confessed that little has been accomplished respecting the causes which may have produced gneiss, mica, slate, and other rocks of the same character. Names of the various compounds and confusedly crystalline rocks we have in abundance, and if the investigation required no other aid we might sit down satisfied; but unfortunately the abundance of these names has confused the subject, and the student has more frequently contented himself with arranging

and disarranging particular mineral compounds in a cabinet, than in investigating their general relations to each other, and the occurrence of the whole in the mass. It will be readily admitted that the difficulty of the subject is very considerable, requiring considerable insight into the exact sciences; but the subject being difficult would seem a good reason why the more advanced cultivators of that science should attack it, offering, as it does, such an ample field for the exertion of their abilities."

We will now proceed to a description of some of the most important inferior stratified rocks.

QUARTZ ROCK. — A semi-crystalline quartz rock is frequently observed in the inferior stratified group, and is associated with nearly all the principal masses. It is sometimes very compact and tolerably pure, while at other times it contains a large quantity of alumina. It is usually granular when pure, but often becomes arenaceous. "In some of these examples," says Dr. Macculloch, "it appears to be a granular crystalline mass; in others it possesses a mixed mechanical and chemical texture; while in a third the rounded aspect of the grains, and the small number of the

points of contact, appear to indicate an origin chiefly mechanical, and resulting from the agglutination of sand." Quartz rock, according to Baron Humboldt, is found in extensive and thick masses in the Cordilleras of the Andes. In Scotland and the neighbouring isles it is abundant.

ARGILLACEOUS OR CLAY SLATE.—That rock called argillaceous or clay slate, and belonging to the inferior stratified group, cannot be distinguished from specimens of the same rock associated with the grauwacke series. Its colour and texture are various, being influenced by the ingredients of which it is composed and the action of extraneous causes.

HORNBLENDE ROCK AND SLATE.—Hornblende rock is generally of a very dark greenish colour. When laminated it is classed among the slates, and its form and appearance are modified by the presence of felspar, mica, and chlorite. Dr. Macculloch classes, under the general term hornblende, all those rocks in which that mineral prevails, including many of those specimens which have been called greenstones.

While writing on this subject, we cannot help feeling a suspicion that the dry details into

which we are entering must be uninteresting to the general reader. To the student, however, they will be useful, as giving him an opportunity of detecting the presence of the different rocks and of giving names to those with which he may meet in his examination of particular districts. The subject is one so extensive, it is impossible to do more than describe in the most general manner the characteristics of the rocks, and to allude occasionally to their associations.

Mica Slate.—Mica slate is generally composed of quartz and mica in alternate layers. This rock not unfrequently passes, by insensible gradations, into gneiss, by the increase of mica and the diminution of the other constituent parts of that rock. It has usually a silvery white colour, but after exposure to the weather becomes yellow. Sometimes it is nearly black. It contains commonly so many crystals of garnet that they may almost be said to form a constituent part. Its slaty structure is often greatly contorted, and large veins of quartz are by no means uncommon.

Chlorite Slate.—Chlorite slate has some resemblance in appearance to mica slate, and is similar in its composition, having chlorite as an element instead of mica. It is frequently as-

sociated with clay slate, into which it graduates, as well as the mica slate, with which it seems to be more intimately connected. We cannot say that it is a very abundant rock, and yet in some districts it may be found in large masses and extending over a considerable extent of country.

TALCOSE SLATE.—Talcose slate, as the name implies, is a rock in which talc is an ingredient; and it is associated with those slates already mentioned, the mica in one instance and the chlorite in another, being replaced by talc.

GNEISS.—Gneiss is a rock composed of the same minerals as granite, but laminated; it is in fact a schistose or slaty granite; and the two rocks frequently unite by almost imperceptible gradations. "Where the quantity of felspar decreases, and the crystals or grains become smaller, if the mica increases in quantity, and is arranged in layers, the rock loses the massive structure, and becomes schistose; we have then a true gneiss. By the reverse of this process, if the quantity of felspar increases, and the mica diminishes, the rock loses its schistose structure and becomes massive, and we have granite again." Gneiss and mica slate are by far the most abundant of all the inferior stratified rocks, and those to

which the others may be considered as subordinate. There are few countries in which they may not be somewhere found at the surface. In the western isles they are abundant, and also in Norway, Sweden, and Russia. In the south of England, north of Scotland, and in Ireland, they may also be studied. It is, however, impossible for us to enumerate the situations in which they appear in foreign countries. Nor can we enter into the theoretical opinions entertained by various writers, or enumerate the arguments employed to support the two opposite conclusions, one in favour of, and the other opposed to, their igneous formation.

THE UNSTRATIFIED ROCKS.

The unstratified rocks are widely distributed over the surface of the earth. They have no regular order, and are found among or associated with rocks of all ages. Sometimes they occur as protruded masses, sometimes as overlying masses, (having the same appearance in position as modern lavas, when they spread over a district after ejection), and at other times as veins. They are supposed by all geologists to have resulted from the ejection of mineral masses

by the action of heat, and we cannot therefore expect to find in them organic remains of any kind. When any branch of scientific inquiry first comes under the attention of observers, many errors, for want of extensive investigation, creep into the received systems, and are not only adopted as facts but made the basis of theoretical opinions. It was thus in reference to the class of rocks of which we are now speaking; they were supposed to have a certain fixed position in the geological series, and to be as capable of arrangement in a particular order as the stratified beds. A more extensive observation has convinced us that they occasionally appear among all the groups, and have acted upon them as disturbing forces.

GRANITE is the rock once supposed to be the lowest of the series; and generally consists of the three simple minerals, quartz, felspar, and mica. It is most frequently found in the highest situations, having been forced, by the action of heat, through the superficial crust of the earth.

The three minerals forming granite are united in different proportions, and even give to different parts of the same mass an altogether various appearance, as the one or the other predominates, and as the crystals are larger or smaller.

Talc or chlorite sometimes takes the place of mica, and this variety is called *protogine*. When small grains of quartz and mica are united with large crystals of felspar, the rock is called a porphyritic granite. When hornblende takes the place of the mica, the rock is called sienite; and the term seems to have been derived from the presence of this variety at Sienna in Upper Egypt, a place from which the ancients obtained much of the rock used in the structure of the obelisks. When felspar is the principal ingredient, the rock is called a felspathic granite, and is usually of a white or a reddish white colour. The French call it *eurite*, and Werner denominated it *white stone*; it is said to be very common in Auvergne, and in its most compact form becomes a porphyry.

It may be here stated that the word *porphyry* is derived from the Greek, and signifies a purple colour. The rock to which this term was first given had this colour; but the word has now a much more extensive meaning, and signifies any compact and finely granular substance containing imbedded crystals. Both the base and crystals of porphyritic rocks are generally felspar. The white stone or eurite is a porphyry.

Granite is extensively distributed over the

surface of the globe, and in our own country appears in Cumberland, Cornwall, and at Dartmoor. It is no doubt a volcanic rock, being frequently found in veins, and having always a character that associates it with the masses attributable to igneous causes. The ejection of granite was not confined to any one period, but has even disturbed the tertiary deposits. By a gradual transition it frequently passes into other rocks, as already mentioned; and Dr. Hibbert speaks of an instance, in the Shetland Isles, where it blends itself with basalt. In Norway and the Isle of Sky granite overlies a fossiliferous limestone; and at Weimbohla it is above the chalk. Professor Sedgwick has described the contact of granite and the oolitic rocks at Broda, and supposes them to have been elevated by it, and also the formation of a breccia of limestone and granite on the north coast of Caithness.

"The aspect of granite mountains," says Mr. Bakewell, "is extremely various: where the beds are nearly horizontal, or where the granite is soft and disintegrating, the summits are rounded, heavy, and unpicturesque. Where hard and soft granite are intermixed in the same mountain, the softer granite is disintegrated and

falls away, and the harder blocks remain piled in confusion on each other like an immense mass of ruins. Where the granite is hard, and beds are nearly vertical, and have a laminated structure, it forms lofty pyramidal peaks or aiguilles, that rise in enormous spires: such are the aiguilles in the vicinity of Mont Blanc, which are far more interesting, both to the picturesque traveller and the geologist, than Mont Blanc itself. The aiguille de Dru is, perhaps, the most remarkable granitic mountain at present known; the upper part, or spire, rises above its base nearly to a point in one solid shaft more than four thousand feet; the summit is eleven thousand feet above the level of the sea."

The common use of granite in building and in the paving of horse roads will render it unnecessary to enter into a description of its appearance; but it may be desirable to remark that those granites are best suited for architectural purpose which have least felspar, as that mineral is subject to decomposition from the atmosphere.

SERPENTINE AND DIALLAGE ROCK. — Serpentine is a magnesian rock, having a dull greenish yellow and bright mottled colour. By its colour, softness, and smooth surface, it may

be distinguished. It derives its name from a supposed resemblance to a serpent's skin, in the variety of its colours, which are for the most part green. It yields to the knife, and some specimens will receive a high polish. When first broken, serpentine has a slightly greasy feel, but this is much more decided when powdered. It is generally supposed that the *lapis ollaris* of Pliny is the rock to which we now refer. Dr. Jameson says it does not occur in either the Hebrides or Orkney Isles, but that it forms extensive hills in Shetland; and that at Portsay there are vertical strata, alternating with marble and talcaceous and hornblende slates. In Upper Egypt and some other places a serpentine is found so soft that it may be turned in a lathe, but resists the action of fire, and it is said that vessels made of it are used for culinary purposes. In the isle of Anglesea, a few miles from the Paris copper mine, several varieties are found, and it forms part of the Lizard point in Cornwall.

"By a mixture of serpentine with talc or steatite, serpentine becomes soft and sectile, and forms the mineral called *pot stone*," which is a soft grey or greenish magnesian rock.

Frequent allusion has been made in this chapter to the remarkable gradations of non-fossili-

ferous rock, but it is impossible to convey to the mind of the reader an idea of the excessive variety in the appearance of these masses. A walk of a few miles over a country formed of primitive rocks will more convince him than any thing that could be said on the subject. In the vegetable kingdom a regular series may be often traced from one class to another, and among animals the separation between the species is not so sudden as might be imagined; but neither of these will give an idea of the intimate connection between rocks. We have another instance of this in the diallage rock, composed of diallage and felspar, which is so nearly allied to serpentine that the latter seldom extends over any considerable district without the presence of diallage. Both serpentine and diallage blend with green stone and other trappean rocks.

TRAP ROCKS.—We must now proceed to examine an interesting class of volcanic rocks, so closely resembling those mineral masses ejected by active volcanoes that it is impossible to deny the identity of origin. They are classed under the generic term trap, derived from the Swedish word *trappa*, a stair; for many of them are arranged in regular forms resembling stairs.

Trap rocks are found in various situations and

in different conditions. Sometimes they are imbedded in other rocks, sometimes they are found overlying them, and at other times intersect them, forming veins and dykes. Felspar and hornblende are the principal ingredients of trap rocks; augite, a mineral greatly resembling hornblende, being sometimes intermixed. The varieties of trap are greenstone, basalt, clinkstone; pitchstone, amygdaloid, trap, and pitchstone porphyries.

Greenstone is a rock consisting of hornblende and felspar, and having a granitic structure. When the felspar is red the rock is called a sienitic greenstone.

Basalt is composed of the same simple minerals, with occasionally augite. It has usually a greenish or brownish black colour, and is so hard that it does not yield to the knife. Its texture is sometimes uniform, but it commonly contains crystals of olivine, augite, and felspar. The decomposition of basalt produces that substance called *wacke*, which is of a greenish or reddish colour, and of a dull earthy appearance. When small cavities containing chalcedony, calcareous spar, and other minerals, exist in a basalt, it is called an *amygdaloid;* and when the felspar greatly prevails, and the rock has a

very compact structure, it is called *clinkstone*, from the sound it gives out.

Pitchstone has the same constituents as basalt, but contains a portion of bitumen. "It may," says a modern author, "be considered rather as a particular form or condition of felspar or basalt, than as a distinct substance, holding to these minerals a relation similar to that which obsidian does to lava. Pitchstone has a black or blackish green colour and a semivitreous appearance."

"The above rocks," says Dr. Daubeny, "have this peculiarity belonging to them, that they occur in connection with all the formations, from the oldest to the most modern, resting on them in irregular tabular masses, occasionally alternating with and still more commonly intersecting them at various angles."

The trappean rocks, like the modern lavas, frequently occur as veins. This might be expected from the mode of their formation. A mass of intumescent matter can only be forced to the surface when a fissure is made in the solid crust superposing the spot where the heat is acting. But a single fissure can scarcely be made in a series of rocks, but various cracks will be opened branching from a central trunk;

all these will be filled by the rising fluid, and being cooled will be permanently fixed within them, forming veins. We may however observe that veins have been produced by intrusion as well as ejection. This remark may be made more intelligible to the reader by an illustration. When a rock is thrown in a fluid state to the surface, it will, obeying the law of gravitation, descend from the higher to the lower points of the district where the ejection happens to take place. It is thus that the lavas thrown from volcanic summits flow down the mountains towards the valleys, and of course increase the height and regulate the forms of the volcanic cones. But there may be, and there is, a strong probability that, in some parts of the ground over which the mineral stream flows, fissures are formed, and into these the lava will penetrate, and, filling them, cause veins similar to those frequently observed to traverse rocks of all ages.

The trap rocks, and especially the basalts, occasionally take a columnar structure. The cause of this was for a long time a subject of doubt, but the experiments of Mr. Gregory Watt removed every objection, and proved that the structure resulted from the slow cooling of

the rock. This gentleman melted seven hundred weight of basalt, and, reducing the temperature, kept it seven days in the process of cooling. When fused it was a dark coloured mass; but in cooling it assumed a crystalline structure.

Fingal's cave, in the Island of Staffa, is an interesting and frequently quoted example of columnar basalt. This remarkable cavern is called by the islanders the cave of music, in all probability because of the wild sound of the waves, which are borne into it with great violence during rough weather and in the winter season. The entire island is basaltic, and on its coast is, as it were, bounded with a row of natural columns. The chasm or cave which has attracted so much public attention is about 42 feet wide and 227 in length. "It would be useless," says Dr. Macculloch, to whom we are indebted for much of our information concerning the western isles, "to attempt a description of the picturesque effect of a scene which the pencil itself is inadequate to portray. But even if this cave were destitute of that order and symmetry, that richness arising from multiplicity of parts, combined with greatness of dimension and simplicity of style, which it possesses, still the prolonged length, the twilight

gloom, half concealing the playful and varying effects of reflected light, the echo of the measured surge as it rises and falls, the transparent green of the water, and the profound and fairy solitude of the whole scene, could not fail strongly to impress a mind gifted with any sense of beauty in art or nature."

We might refer the reader to many other examples of the crystalline structure of basaltic rocks, and enlarge on the arrangement and probable formation of all the non-fossiliferous masses. Sufficient, however, has been already said to direct the studies of the reader; but to fill up the sketch given, in the preceding pages, of the science of geology, both observation and reading will be found necessary.

GEOLOGY

OF THE

WATERING PLACES.

Geology has of late become a fashionable science, and, as such, every opportunity which leisure offers is taken by those who study it, to acquire some practical information concerning the arrangement of rocks and the distribution of organic remains. There is in the science a startling novelty exceedingly adapted to attract the attention of the young, which is well sustained by the necessity for doing as well as thinking. Science is not, to the majority of persons, sufficiently attractive to induce a careful, much less a thorough, investigation. The human mind is averse to labour, and requires a strong discipline to overcome its indisposition to study; so that when it meets at the very outset of its exertions with great impediments it quickly renounces its resolution, and is content to indulge sloth at the expense of the pleasures to be

derived from knowledge. Geology is, like all other sciences, burdened with technicalities, and in this aspect is repulsive to the student; but it fortunately offers inducements for investigation which outweigh the natural indisposition to thought. The curiosity is excited by the report of discoveries which may be classed among the romances of ancient times; the ambition is roused by a hope of making some discovery ourselves, the love of collecting may be satisfied, and the enjoyments of life may be at the same time increased, rather than diminished, by the necessity of pursuing the study abroad. These are probably the causes which have rendered geology a populr pursuit among those who designate themselves the reading public.

The principles of geology must be acquired from books, but to know the science itself, and to be able to form an independent opinion, rocks must be studied in situ, and the student must become a collector. We have known many young persons who, having read extensively upon the subject, have felt their curiosity excited, and desired to put their information in practice. To those who have had the opportunity of travelling, the task has been an easy one; but to those who seldom leave their homes, and then

spend their time in some place of fashionable resort, the task is difficult. Many, however, do attempt, in such places, to obtain a little practical information, but for want of an acquaintance with what has been done by others, their attention is not directed to the most interesting features of the district, and they therefore return home with a very trifling addition to their previous stock of knowledge. For such persons the following pages are chiefly intended, but there is another class to whom, it is hoped, they will also be interesting.

There are few persons who do not spend a portion of the summer in a watering-place, and those who have no particular object of pursuit cannot but feel, after a few days absence from their customary engagements, a want of some mental occupation. A knowledge of botany, conchology, or any other branch of natural history, would supply a pleasing means of employment; but, of all the various pursuits to which a person may, under such circumstances, apply himself, none can offer more varied amusement and instruction than the science of geology. To those who find themselves, under such circumstances, unhappy for want of amusement, we offer our pages.

The author has endeavoured to collect from the transactions of the Geological Society, and the Philosophical Journals, the observations of men of science upon the rocks and fossils of those localities which have become fashionable as summer resorts. With some of these districts he is personally acquainted, and, in speaking of them, has blended his own observations with those of other writers. In other cases he has been compelled to depend upon the observations of others. To young persons this brief view of the geology of watering-places will, it is hoped, be especially valuable, not only as explaining the character and super-position of the strata, but as directing their attention to the organic remains peculiar to the several deposits.

THE ISLE OF SHEPPEY.

The Isle of Sheppey, in the county of Kent, is separated from the main land by an arm of the sea called the Swale, which was a long time considered a part of the Thames, and was the usual passage for shipping between London and the North Foreland. "When the wantsume," says Bradley, "which separates the Isle of

Thanet from the rest of Kent, was also navigable, this channel (the Swale), besides being the most sheltered, must likewise have been the most direct way from the Downs to London; but, as that way became progressively choked up by the sands, and as the increase in the size of the ships enabled them the better to withstand the violence of the waves, the Swale was gradually deserted, and is now only used by the vessels immediately employed in the trade of Kent."

The Isle of Sheppey is almost thirty miles in circumference, thirteen in length, and six in its greatest breadth. A large part of the island is marsh land, which is far from unproductive to the agriculturist, being in most places covered with a rich mould. The prevailing soil is a strong, stiff clay. The parishes of Minster and Eastchurch are very fertile, producing excellent corn. The southern portion of the island is flat and uninteresting; the interior is diversified and beautiful. The cliffs which stretch along the shore for the length of nearly six miles are peculiarly romantic, and in some parts have a height of more than a hundred feet, but gradually decline at each end.

It is not certain by what name the island of

Sheppey was known to the Romans. It is supposed to be one of the islands mentioned by Ptolemy as situated in this part of England, but whether it is Goliapis or Counus cannot be decided. Camden and Batteley suppose it to have been the former, Leland and Lambarde the latter. By the Saxons it was called Seapige, or Ovinio, because of the many sheep fed on it, and for the same reason, no doubt, it received the name it now bears.

To the geologist, the cliffs are the most interesting part of the island from the immense number of fossils they contain. They are composed of clay, and belong to that formation called blue or London clay. By the constant washing of the tides at their base, and especially when driven by easterly winds, they are continually worn away, and the upper parts, being left without a support, are thrown on the beach, where the fossils are left. "But, alas," says Mr. Jacobs, in a little pamphlet published in 1777, "one disagreeable circumstance attending a considerable part of the fossils here collected is, that they are so much impregnated with pyrites that, after being for some time placed in a cabinet, the salts thereof shoot and entirely destroy them."

The mineral substances found in the blue clay of Sheppey are iron pyrites, sulphate of lime, and selenite.

The iron pyrites is so abundant that in the last century the proprietors of the manors of Minster, Shurland, and Warden, gave liberty, at a fixed value, to the different owners of the copperas works in the neighbourhood to collect this mineral, and the poor who were employed by them received a shilling a bushel for the trouble of collecting it.

The nodules of lime, which are lodged in the cliff in great numbers, are generally of a flat or oval shape, and of a yellowish colour. They are of various sizes, the largest being about two feet in length: it is from them that the Roman cement is made. They were once found in great abundance, but since they have been applied to a useful purpose have become comparatively scarce.

Selenite is found in great abundance.

Some of the author's happiest recollections are connected with a short residence in the island of Sheppey many years since, where he formed a friendship with a gentleman who was then, like himself, a tyro in science, but is now one of the most eminent philosophers of the western world.

In the year 1830 he discovered, when visiting some friends in the island, a substance which was afterwards found to be a chloride of carbon, but the description of this curious substance, which was written at the time, has not, we believe, been made public. It may, however, be found to have some interest, and has been therefore inserted at the end of this volume.

We must now endeavour to describe some of the most common and remarkable organic remains, all of which are more or less impregnated with pyrites.

Some of the vegetable remains are exceedingly well preserved. A vast number of fruits have been discovered, and fossilized wood, of which there are several varieties, is common. We have seen large trunks of trees obtained from the clay, and these, when polished, exhibit the grain clearly, most of them resembling oak in structure, but some having the open grain of fir.

The teeth and palatal bones of fish, particularly of the shark, the heads of fish, many of a large size, are also not unfrequent. The vertebræ of the shark, and parts of the bodies of fish with the scales on them, are also sometimes found. Many crustacea also are collected,

among which, varieties of the tortoise, lobster, and crab, are most common.

The shells are far too numerous to name with any degree of particularity. The nautilus, trochus, buccinum, turbo, and oyster, are the most common.

The London clay forms the cliffs at Southend, and also at Harwich, on the Essex coast. It has there nearly the same character as in Sheppey, and need not therefore be more particularly described. A visit of a few days to either of these places will enable the student to collect a large number of fossils. The genera to which they belong may be known from a slight acquaintance with conchology; the species may be determined by reference to Sowerby's Mineral Conchology.

MARGATE, RAMSGATE, AND DOVER.

The chalk formation is extensively developed in Kent, and upon the coast many fine sections are exhibited. It may be conveniently studied at either Margate, Ramsgate, or Dover. The whole of the Isle of Thanet consists of chalk, and it forms a fine range of cliffs on the sea shore. Dover, however, is peculiarly interesting, as presenting this rock in its various states,

with and without flint. Near Walmer Castle the chalk is seen to rise from beneath diluvial deposits, and may be traced in a comparatively low cliff to St. Margaret's Bay, a distance of nearly five miles, where it has an elevation of about 200 feet. From Dover it extends about five miles westward towards Folkestone. The highest point of this range of cliff is about a mile north of Folkestone, and has been measured at 575 feet. The highest point of the hill on which Dover Castle stands is about 390 feet above the level of the sea. The entire range of cliff is about thirteen miles.

One part of the cliff between Dover and Folkestone will be interesting to the lover of scenery, as well as to the geologist. "In this long range of cliffs," says the author of the Outlines of the Geology of England and Wales, "which in many places forms an immediate barrier to the sea, it is not to be expected that every part should be equally accessible to investigation. Between Deal and Dover there is but little difficulty, nor for nearly half the way from Dover to Folkestone; but in the latter half of that distance an immense fall, or rather, it should seem, repeated falls have taken place, so that that part of the cliff of which the beds

remain in situ is, at its extremity, beneath the signal house, nearly a mile from the shore. The ruin lying between this cliff and the sea, for about three miles in length, affords scenery inferior in beauty to the under-cliff of the Isle of Wight, only because, from its want of soil, it is less susceptible of cultivation; while, from the same cause, its grandeur is more striking. The greater part of it, however, is sufficiently covered by herbage to have become a pasturage for cattle. The cliff bounding this ruin towards the sea is, from its position, evidently not in situ, and it is equally clear that the enormous masses of which it is composed have fallen forward from near the summit of the cliff in situ."

The cliffs from Walmer Castle to St. Margaret's Bay consist entirely of chalk with numerous flints, the beds of flint being on an average not more than two feet apart. These beds are made up of separate masses of flint, but to the west of St. Margaret's Bay a stratum of flint, about an inch and a half in thickness, rises from the beach, and may be traced continuously for two miles. Soon after its appearance a similar stratum, about half an inch in thickness, is observed, and may be followed for nearly a mile, about twenty feet below the former. The

upper part of the cliff at Dover consists of the chalk with flints. During the late war, four chambers, about twenty feet wide, and fifteen feet high, were formed in this rock beneath the fortifications, and their roofs consist of a solid mass of flint, similar to the strata just mentioned, but of greater thickness.

Beneath the chalk with regular layers of flint, the flints are interspersed through the mass, and organic remains abound. This is not a distinct bed, but forms the lower part of the chalk with numerous flints. "The whole bed has from below a greyish appearance; and by this it may be traced for at least two miles, dipping gently in its course, which terminates at the foot of the cliff, just at St. Margaret's Bay, four miles on the east of Dover. It may be seen along the cliff, at the back of the town of Dover, and is visible west of it, as forming the upper part of Shakspeare's Cliff, and terminating at the summit of the cliff about two miles beyond it."

Beneath the chalk with interspersed flints, there is a bed of marl, two or three inches in thickness, which separates it from the chalk with few flints. The lower part of Shakspeare's Cliff, and the whole of the low cliff between

Shakspeare's and the town of Dover, except the summits, are composed of the chalk with no flints, and it may be traced westward towards Folkestone for nearly four miles.

The chalk marl, which is the inferior member of the chalk formation, rises from the beach at the foot of the low cliff, and may be traced for some distance along the coast.

This brief sketch of the geology of Dover and its neighbourhood will probably be found a sufficient guide to those who may visit this locality, and wish to observe for themselves, but a much more elaborate essay will be found in Conybeare and Phillips's Geology of England and Wales.

The chalk is, on many accounts, a peculiarly interesting formation. It is the most recent of the secondary rocks; it abounds in organic remains, which are well preserved and easily obtained; and it gives evidence of the existence, during its formation, of a most remarkable condition of physical causes, both as regards the production of the chalk itself, and the fossils it contains.

Having had opportunities of forming a large collection of fossils from the chalk of Kent, a catalogue of those we obtained has been in-

serted in the appendix, with such remarks as appeared necessary. It was written and printed for the use of some friends in the year 1829, since which time but few opportunities have offered of extending our information concerning these interesting remains. The fossil fish in the chalk of Kent are not so numerous, nor so well preserved, as those of Sussex; and it is a singular fact, so far as our own experience gives an opportunity of forming a conclusion, that the few remains which are obtained in Kent have been found in a limited number of localities. The teeth and palatal bones are numerous throughout the upper chalk, and seem to have been distributed through the mass in the same manner as the shells, but the other remains of these animals have been preserved in but few situations.

It must not be supposed that the chalk formation terminates on the eastern coast of England. On the opposite coast of France the same rock is observed. Hence it has been supposed that there was once a continuity of land, and that the little island we inhabit was, at some distant period, a portion of the continent of Europe. This separation may be accounted for by imagining the intervening space, now covered by

water, to have sunk during one of the great physical revolutions which followed the formation of the chalk, or by an eruption of the sea washing away the intermediate mass between the opposite coasts. There may be a difference of opinion as to the nature of that event, but when it is ascertained that the chalk cliffs between Calais and Dissant, opposite to those of Dover, have the same subdivisions, no doubt can remain as to their former union.

BRIGHTON.

The town of Brighton is built on an accumulation of water-worn materials, deposited in a hollow of the chalk, which forms the sub-stratum of the district. In this deposit are found the teeth and bones of the elephant, horse, and other quadrupeds, as well as various organic remains belonging to older formations, of the debris of which it consists. The same diluvial deposit, for by this name the superficial beds of gravel and drift are still known, may be observed in the cliffs.

The chalk at Brighton is similar in its general characters to that on the coast of Kent, so that we might pass from this district to those inter-

mediate localities on the coast which are so well known to visitors generally for the beauty of natural scenery, and to geologists, as offering the most interesting sections in this island of the rocks between the chalk and oolites. We cannot, however, pass Brighton without calling the attention of the reader to Dr. Mantell's brief description of the cliffs near this fashionable watering-place, which, in a few words, conveys all the information that is necessary to direct the researches of the stranger. "At Brighton the cliffs are composed of an accumulation of diluvial substances, restig up on the solid chalk, which there constitutes the sea shore, and continues to Rottingdean. From thence to Newhaven the cliffs are nearly perpendicular; and on the western side of the harbour rise into an irregular elevation, called Castle Hill, the upper part of which is composed of numerous beds of the plastic clay formation; the lowermost consisting of the flinty chalk. On the opposite side of the river a low mound of chalk, capped with a bed of plastic clay and ferruginous breccia, appears at Chinting Castle. Proceeding eastward, towards the signal house, near Seaford, the chalk rises to a considerable

height, and forms a majestic line of cliffs from thence to Cuckmere River; and terminate in the magnificent promontory of Beachy Head, which is nearly six hundred feet above the level of the sea. Along this line of coast ammonites of a large size, plagiostoma, echinites, and other productions of the chalk, may be obtained.

FOLKESTONE AND HYTHE.

Between Folkestone and Dover, not far distant from the former place, the chalk marl may be seen rising from beneath the chalk. This rock abounds in ammonites, hamites, nautili, turrilites, and other fossil shells. The chalk marl rests on the firestone, and this rock on the gault or Folkestone marle, all of which are well exposed.

The same series of rocks may be seen on the Sussex coast, between South Bourne and Bexhill. In the low cliffs, near South Bourne, the chalk marl appears beneath the chalk, resting on the firestone, and may be traced to Shoreham River. The fire-stone differs greatly in its mineralogical characters in different localities. In some places its transition from

the marl is so gradual that no line of separation can be observed between them, but in others they are sufficiently distinct to be seen by a casual observer. In some situations it occurs as a loose sand, and in others as a sandstone, sufficiently hard for building purposes. In the west of Sussex it appears as a bluish marlstone, and is called malm rock. Its character on the Sussex coast is well described by Dr. Mantell in his Geology of the South-east of England, from which work we again quote.

"The low cliffs near South Bourne expose a section of the arenaceous variety of the fire-stone. Eastward of Beachy Head, and to the west of Holywell quarries, the chalk marl is seen under the chalk without flints, dipping about 5° to the south-west. Proceeding along the beach, a bed of greyish sand emerges from beneath the marl, to the east of the first martello tower: this quickly rises, till it constitutes one half of the cliff, and beneath it is seen a stratum of friable sandstone, of a deep green colour; at the distance of about forty or fifty yards, the cliff, which is twenty feet high, is entirely composed of these strata, with the exception of a covering of alluvial loam on the

summit. The alluvial tract called "the wish" obscures the beds near this spot, but they re-appear at about a hundred yards to the eastward, when the firestone forms the base of the cliff, and is covered with a rubbly marl, of a greenish-yellow colour; the latter being twelve, and the former six, feet in thickness. Approaching the sea-houses, the firestone occupies the middle of the cliff, resting on grey marl, six feet thick, with scarcely any intermixture of sand: chalk marl, regularly stratified, lies above it; and, were we to judge of the geological character of the firestone from this locality only, we should certainly consider it to be a subordinate bed of the chalk marl. At the sea-houses the firestone gradually descends, and forms the base of the cliffs, which are there of an inconsiderable height; the buildings along the sea shore obscure the strata to the eastward, and prevent the junction of the firestone and gault from being seen; specimens of the latter are observed, however, on the shore at low water, and it rises to the surface not far from the library. The fossils found in the firestone of South Bourne are, with but few exceptions, similar to those which are in the chalk marl: viz., ammonites vari ans, mantelli, turrilites, scaphites, &c."

Beneath the firestone are found the gault or Folkestone marl, and the Shanklin or lower green sand, both of which are well developed in the cliffs near Folkestone and Hythe.

The gault is a stiff marl, varying in colour from a light grey to a dark blue, and abounding in ammonites, nautili, and other organic remains. The cliffs to the east of Folkestone are formed of this rock.

HASTINGS.

No person interested in geological pursuits should visit Hastings without having as his companion Dr. Fitton's book on the subject. Hastings is one of the most pleasing spots selected as a fashionable watering-place, and the cliffs on either hand present bold sections of a series of rocks which cannot be studied with equal advantage in any other situation; but, as every curious observer will avail himself of the assistance of the work already mentioned, a very brief and general account of the geology of the district is all that will be required.

The cliffs at Hastings consist of those beds which form the central and lowest groups of the wealden formation, otherwise known as the

Hastings and Ashburnham beds. Of this singular formation, the weald clay, with its subordinate beds of sandstone and shelly limestone, is the most recent member, and has been already spoken of as forming the cliffs near Hythe and East Bourne. By an examination of a geological map it will be observed that the weald clay completely surrounds the Hastings beds; and, by a section of the coast, it will be evident that all the deposits upon this interesting line of cliff have been disturbed, and those at Hastings are thrown into the form of an arch, dipping at each end under the weald clay.

Mr. Webster was the first geological investigator of the district. In 1824 this gentleman read a paper before the Geological Society, in which he described the line of coast, extending from the White Rock, on the west of Hastings, to Cliff End, near Winchester on the east. "Along this extent," he says, "several valleys of denudation occur, which have separated the cliff into different portions. One of these valleys divides the White Rock from the West Cliff, on which are the ruins of the ancient castle; in another, which divides the East from the West Cliff, the town of Hastings is built. In the middle of the East Cliff is the romantic val-

ley where the stream called Eaglesbourn forms the well-known fish-ponds; and to the east of East Cliff, and between it and Fairlee Cliff, is the place called the Govers. At Cliff End the cliff terminates, and gives place to the valley that goes up to Winchester."

The Hastings beds may be described generally as consisting of a great variety of sands and sandstones, grits and shales. The upper member of the formation, or that which emerges from immediately below the weald clay, is a calcareous rock, sufficiently hard in many places to be used as a suitable material for repairing the roads. Beneath this is seen at East Cliff (and an interesting section of it was exhibited in the white rock) a dark coloured stratum, which is the Tilgate stone. This lies upon a thick bed of white sandstone, which rests upon beds of clay and shale, containing lignite and silicified wood. Under the shale is another bed of sandstone. "The lowest strata visible in this series consist of a dark coloured shale, which is seen at the Govers and Cliff End, and contains small roundish masses of sandstone, together with several layers of rich argillaceous ironstone; with these are found abundant thin layers of lignite, and

innumerable fragments of carbonized vegetables, among which, ferns are recognisable."

The Hastings beds have been classed in three sub-formations called the Horsted sand, the Tilgate beds, and the Worth sand and sandstones.

The Horsted sands, so called because they are well developed at a village of that name, form the uppermost member of the Hastings beds, and consist of variously coloured sands and sandstones, with occasional masses of ironstone. They may be traced at Bexhill, and on the top of West and East Cliff.

Beneath the Horsted sands is found the Tilgate stone, which occurs in layers varying from two or three inches to two feet in thickness, and resting on a blue clay or shale which separates them from the Worth sands. These beds have become extremely interesting to the geologist as the repositories of a vast multitude of organic remains, especially the bones of saurians. They are exhibited in a very striking manner in East Cliff, which rises to a height of from four to five hundred feet, and extend to within a few miles of Winchelsea. "The upper part of these cliffs consists," says Dr. Mantell, "of yellow

and ferruginous sand, in which two or more layers of the Tilgate stone are imbedded; the middle portion is composed of the Worth sand and sandstone; and the lowermost of ferruginous sand and dark shale, with carbonized vegetable remains, lignite, and rich argillaceous iron ore." The following section presented by the cliffs near Eaglesbourn will convey an idea of the whole.

1. Uppermost beds; fawn-coloured sand and friable sandstone, about 10 feet.

2. Tilgate stone, from 2 to 6 feet.

3. Clay, loam, &c., alternating with sand and sandstone, containing lignite, &c., 20 feet.

4. White and fawn-coloured sandstone (Worth sandstone), 100 feet.

5. Ferruginous sand and sandstone, alternating with dark blue shale and reddish clay; lignite, ironstone, vegetable remains; these beds form nearly the lower third of the cliff. The strata are slightly inclined to the east.

These ferruginous sands and sandstones belong to the Ashburnham beds, and form a part of the lowest member of the wealden formation.

LYME REGIS.

As it is not our intention to describe the geological structure of the entire English coast, but only to point out some of the most remarkable features of those parts which are visited as places of occasional retirement, or periodical fashionable resort, we must pass by the coast of Hampshire, the Isle of Wight being sufficiently described in a former page. The coasts of Dorset and Devon are peculiarly interesting to the geologist, presenting at almost every part bold and characteristic sections of the various secondary rocks of which they consist. The first place of importance is Weymouth, which, as well as the island of Portland, has long attracted the attention of the practical geologist. An elaborate memoir of the geology of Weymouth and its vicinity was read before the Geological Society in the year 1830 by Dr. Buckland and Mr. De la Beche. The district is spoken of, by these justly celebrated observers, as one of great importance, from its position near the south-western termination of several principal formations of the island, from the existence of a coast section, which forms an interesting ob-

ject of comparison with the north-eastern terminations of the same strata on the coast of Yorkshire, and from the remarkable exhibition of the effect of those disturbing agents which have acted upon the strata since the period of their consolidation. As it does not enter within the range of our inquiries to examine this district, we must refer the reader to the memoir already mentioned,* and Professor Sedgwick's remarks on the same subject in the Annals of Philosophy.†

Mr. De la Beche was the first geologist who published an account of that portion of the coasts of Dorset and Devon, from about three miles west of Bridport Harbour to Sidmouth.‡ The cliffs, proceeding from Bridport Harbour to Sea Town, are not of great elevation. They at first consist entirely of beds belonging to the oolitic series, but the lias is soon seen at the base of Down Cliff rising from beneath them, and may be traced, almost without interruption, as forming the lower and larger portion of the cliff, for a considerable distance beyond Lyme

* Geological Transactions, second series, vol. iv.

† Annals of Philosophy, vol. xxvii.

‡ "Geological Transactions," second series, vol. i.

Regis. At the highest point of Down Cliff the green sand formation is seen resting upon the oolites, and the same rock lies immediately upon the blue lias at Golden Cap, Shorn Cliff, and Black Ven. Golden Cap is a remarkable cliff, consisting, as already stated, of blue lias and green sand, about five miles east of Lyme, and has an elevation of about 600 feet above the level of the sea. At Black Ven, which is situated between Charmouth and Lyme, regular, compact, and unbroken beds of chert appear in the green sand. The same substance occurs at Golden Cap Hill and Shorn Cliff, but as loose, angular, shattered fragments.

To the west of Lyme lias is again observed at the base of the cliff, but the connection of that rock with the green sand which rests upon it, as in the portion of the coast already described, is concealed by a beautiful undercliff, composed of fallen masses of green sand and chalk. At the most westerly point of the Ware Cliff, chalk may be observed, resting upon the green sand, and it forms the caps of the hills of Pinhay, Whitelands, Charlton, Rusedon, and Dowlands. Beyond Axmouth it appears again at White Cliff and Beer Head, reposing on

green sand. Proceeding west, the chalk still continues to cap the hills, decreasing in thickness, and disappears at Dunscombe hill, a short distance to the east of Sidmouth.

At Dowlands, near Axmouth, the red sandstone formation makes its appearance; and at Axmouth Point the green sand is seen immediately above it. At Seaton it forms some low cliffs, and from thence, with the exception of White Cliff and Beer Head, it constitutes the lower part of all the cliffs to High Peak, on the west of Sidmouth; proceeding westward, it forms the entire cliffs as far as Babbacombe Bay, where it rests on limestone. The conglomerate at Teignmouth includes large rounded masses of porphyry, from a few inches to two or three feet in diameter; and, between Teignmouth and Babbacombe Bay, it contains small pebbles of the same limestone which it rests upon at the latter place.

The green sand in the neighbourhood of Lyme Regis contains many characteristic and well preserved fossils; but the collector will be chiefly interested in those of the lias. The remains of the icthyosaurus are not rare, and many other fossils are found in abundance, but chiefly at Black Ven. The student will also

be much interested in the examination of the faults in the neighbourhood of Lyme, to which we would especially direct his attention.

TORQUAY.

The geology of Tor and Babbacombe Bays was examined by Mr. De la Beche in the year 1827, and the result of his observations may be found in the Geological Transactions.* The coast sections in the vicinity of Torquay are peculiarly interesting to the geologist, though this vicinity will afford a less variety of fossils to the collector than many others which might be mentioned. The principal rocks are the Exeter red conglomerate, the carboniferous limestone, the old red sandstone, and some varieties of trap.

The Exeter red conglomerate is well exhibited in Babbacombe and Tor Bays. It contains fragments, which are usually small, of carboniferous limestone and other rocks; but there is another variety, in which some of the fragments are of great size, being often a ton or more in weight. The cliff extending west from the Ness Point at Teignmouth "exposes a section

* "Geological Transactions," second series, vol. iii., p. 161

of this rock, which varies from fine-grained to coarse, the latter greatly predominating." At Oddicombe sands there is a fault occasioned by the intrusion of trap-rock. The same rock may be traced from King's Kerswell, south-west, to Tor Abbey sands, resting upon limestone and old red sandstone. A good section is also presented at the Corbons, a small cliff at the southern extremity of Tor Abbey sands.

The rock called carboniferous limestone by Mr. De la Beche, in his memoir on this district, is that usually referred by geologists to the transition series. But, as this limestone rests on the old red sandstone, contains fossils found in the carboniferous limestone, and resembles it in its mineralogical features, the author has no doubt as to the propriety of placing it as a part of the carboniferous series. "The limestones in the vicinity of Torquay," says Mr. De la Beche, "are much disturbed, as are also, more or less, all the stratified rocks of the district. These beds are observed to be contorted along the whole coast, from the town to the point opposite the Shag Rock; they seem, however, to have a general dip away from the old red sandstone, between which and the body of limestone the argillaceous shale is always interposed."

The limestones and argillaceous shale which appear on the coast from Babbacombe to Black Head are also much disturbed. At the latter place a thick bent stratum of limestone was observed included in the solid trap. " Hope's Nose, with the Leadstone, Oarstone, and Thatcher rocks, lying immediately near it, are composed of limestone, much contorted at the cove north of Thatcher. This mass of limestone is detached from the limestones on the west, that is above the level of the sea, and beneath they are probably connected with the Torquay beds, for the Thatcher rock is composed of them. Kent's Cavern is situated in these limestones." The same beds, from Berry Head to Saltern Cove, near Goodrington, on the south of Tor Bay, are also much disturbed.

To the cause which elevated the trap rocks may be attributed the disturbance of the rocks of this district; and they are, in various places, found intruding among the stratified masses. To the east of Babbacombe there is a small headland, chiefly consisting of greenstone; and, to the west of the same place, there is another, formed of greenstone and greenstone porphyry. Trap also occurs among the limestones between Babbacombe and the northern head of Anstro

Cove; but the largest mass is at Black Head, near Ilsam, which is composed of it.

Near Hope's Nose there is a raised beach, which was described by Mr. Austen, in a paper read before the Geological Society in November, 1834. It rests on the limestone already described, and the lowest part of the bed, which is about seventeen feet thick, is thirty-one feet above the ordinary line of high water. The lowest part is a coarse conglomerate, and above it, one that is finer contains the remains of recent species of shell-fish in considerable abundance. The upper portions of the bed are less compact, and the highest closely resembles a modern beach. A similar deposit encircles the Thatcher rock.

SALTCOMBE.

The village of Saltcombe is situated on the southern coast of Devonshire; and, although unknown as a fashionable resort, is frequented by many who seek the quiet of nature, either as a relief from daily toil, or to restore health. To the geologist it will be found a most interesting spot, if we may form an opinion after a ramble for a few hours over the neighbouring

country. It was our good fortune to visit this portion of Devonshire in the year 1832, and the interest which it excited has not been destroyed by the lapse of time.

The estuary of Saltcombe is an arm of the sea which flows to Kingsbridge, a small town, delightfully situated in a rich and fertile district. The clay slate formation occurs here, and many interesting sections may be observed. The rock has been greatly distorted, and presents all the various contortions of strata which convey so much information to the young geologist when viewed for the first time. In many places it is traversed by veins of quartz, some of which are of considerable extent. Duncombe Hill, near the town of Kingsbridge, is traversed throughout by quartz veins. The clay slates of this district vary greatly in texture and colour, from a light grey to a yellowish red. There are many quarries in which the rock is obtained for building purposes, but the slates of the finest quality are procured from the Moulescombe pits, which should be visited by every geological student.

Sailing down the estuary, the clay slate may be observed on both sides for some distance, but near Halwell wood point, on the left, the mica

slate makes its appearance. At South Sands, near the mouth of the estuary, the same rock is presented in bold rugged cliffs. Here also may be observed a mass of chlorite slate, which again makes its appearance near the village of Hope, once celebrated for the extent of its contraband trade. The coast, which is bold and precipitous, consists of mica slate, and the flanks of the jagged cliffs are covered with the debris formed by the beating of the ocean and the action of the atmosphere. This rock is, like the clay-slate, traversed with veins of quartz, and iron-stone occurs in large masses. On the eastern side of Hope Cove, the mica slate has no perceptible stratification, and bears evident marks of igneous action. The village itself lies in a valley open to the sea, and to the east of it may be seen the junction of the chlorite and mica slates.

From the lofty peaks, known as the Bolt Head and Tail, extensive views of the ocean are obtained. Between these two points there are some curious fissures in the mica slate, called the Whipstone Pits, some of which are five or six yards in width, and of considerable depth.

Such are the geological features of the district around the village of Saltcombe, as far as

we were able to observe during a short visit in the neighbourhood, and they are here introduced, not because they give any adequate description of the district, but because the locality has not yet, we believe, been examined by any other person.

SCARBOROUGH.

From the southern coast of England we must now withdraw the attention of the reader, and direct it to the northern. For our acquaintance with the geology of Yorkshire we are chiefly indebted to Professor Phillips, and, from his description of the coast, we shall endeavour to prepare a brief account of the geology of Scarborough and Whitby, the towns most frequently visited by those who resort to the watering-places on the northern shores of England.

In a walk from the spaw, at Scarborough, to White Rab, it will be observed that the lowest part of the cliff consists of a carbonaceous grit, and, superposing it, a carbonaceous shale and thin sandstone. "It is here very curious to observe," says Mr. Phillips, "the peculiar appearances of the carbonaceous sandstone. The frequent and remarkable curvature of the beds,

the unequal intermixture of shale among them, and the dispersion of carbonaceous fragments through the mass, leave no doubt of the agitation of the water which left this curious deposit. The remainder of the cliff consists of diluvium, which from the spaw to the bridge occupies the entire coast. The gravel beds behind the spaw are spoken of as consisting entirely of lias and moorland sandstone, and containing many ammonites, gryphææ, pectens, and other fossils peculiar to those rocks.

The Castle Hill, which rises suddenly from the water, and attains a height of 270 feet, will be found the most interesting spot to the geological student. The first rock that is seen above the pier is a ferruginous sandstone, called Kelloways rock, and so named because it has a situation similar to that of the bed at Kelloways, in Wiltshire, and contains the same fossils. A rock called the Oxford clay superposes the Kelloways. It is, in fact, a grey argillaceous earth, and has no resemblance in its mineralogical characters to the heavy clay of Oxford, but it has the same relative situation, and is therefore known by the same name. It passes into a calcareous grit, upon which repose some beds of coralline

oolite. "These strata decline on the eastern face of the hill, so that the Kelloways rock sinks below the level of high water, and at a projecting point Oxford clay keeps the foot of the cliff, but soon rises again. Where the hill fronts the north, they ascend towards the drawbridge. The fort on the northern face of the hill is levelled on nearly the lower beds of coralline oolite; of this rock thirty feet appear on the hill above: its whole thickness here is nearly forty feet. Below are about eighteen feet of solid calcareous grit beds. These rest on three layers of hard calcareo-silicious balls, lying in soft yellow sand, twenty-eight feet thick: then succeed fifty feet of calcareous grit, hard above, but graduating below to the next stratum, Oxford clay, which is one hundred and thirty-five feet thick, and occupies the remainder of the hill to high water mark." The Kelloways rock is rich in ammonites, gryphææ, aviculæ, and other fossil shells; in the cornbrash are found terebratulæ, trigoniæ, and others, which may be collected in abundance from the blocks strewn on the sands. The Oxford clay, Kelloways rock, and cornbrash, are not upon any part of the Yorkshire coast better developed than at Scarborough.

WHITBY.

Whitby is a most favourable situation for the study of the lias formation, which first appears at Blue Wick, and "may be traced along the shore by Whitby, Runswick, Staithes, Boulby, and Saltbourn, and every where washed by the sea, except in the space between Whitby and Sandsend, where it is depressed by extensive dislocations."

The lias beds are divided into two principal parts by a thick series of sandy and irony beds, abounding with conchiferous remains, and the parts thus divided are termed the upper and lower lias shales. As alum is obtained in large quantities from the upper, it is termed alum shale. The interposed strata are analogous to the marlstone of Lincoln and Northamptonshire. Near to Peak House there is a great dislocation, the lias beds being lifted on the northern side "to such a degree that some conchiferous beds, which are usually four hundred feet in the lias, appear considerably higher than the top of that formation on the south." To Robin Hood's Bay the cliffs are composed of the deeper lias shale, but about a mile to the north of Bay-

town the deep shale disappears in consequence of the rapid declination of the strata, and in about two miles the marlstone beds also sink, and from that place to Whitby the upper lias shales alone are seen. The irony sandstone at Blue Wick, to the south of Robin Hood's Bay, is peculiarly rich in fossils. "At a point near High Whitby the series of sandstones and shales is very complicated. A sandstone bed, seventy-four feet below the summit of the cliff, contains a great number of cylindrical fossil plants jointed like canes, or rather like equiseta." From High Whitby the cliffs diminish in height, and at Whitby harbour there is a dislocation of the strata, which causes them suddenly to disappear, so that the cliffs from the north of the harbour to Sandsend, where the upper lias shale again appears, are almost entirely composed of diluvium.

Brief as the account of the geology of the watering-places, given in the previous pages, has necessarily been, it will not, it is hoped, be destitute of interest, or altogether void of a higher value to the geological student. It will not be sufficient to satisfy the diligent observer of nature, though it may aid in directing his researches. But it will be chiefly valuable to

those persons who are unacquainted with the science as a practical pursuit; and, as no attempt has been made in any other work to give the same information, it must be useful to every person who is interested in an elementary work on the science of geology.

APPENDIX.

OBSERVATIONS ON A CHLORIDE OF CARBON.

THE changes which take place in the living body are so much controlled by the operations of the vital principle, that it is very difficult to account for the production of many substances that are found to compose it, because there is a constant disturbance, which prevents the usual play of chemical affinities. After death has taken place, the attractions of the particles act energetically upon each other, producing compounds of a more simple form, in a manner that we can readily account for by the laws of chemical affinity. There are cases, however, in which nature appears to depart from her usual course, and to produce substances of a complex character in an unaccountable manner.

Of one of these substances we are about to speak. As we were wandering along the beach of the Island of Sheppey one fine day last summer, we observed a substance, having the appearance of an efflorescence, on one of the septaria which are found in great numbers upon the shore. The coast of this island, looking towards the north, is very precipitous, but owing to the land-springs, and the nature of the sub-stratum, landslips are very frequent; many acres are in the course of

the year precipitated into the sea, and the debris extending a long way beyond low water mark, causes the beach to shelve very gradually to seaward. These slides uncover large masses of septaria (argillo-ferruginous limestone), which are burnt in the dock-yard to make a cement that has the property of setting under water. Upon one of these the substance we are about to describe was observed.

At first we mistook it for nitrate of potash, but on closer examination, we found it could not be that substance. It had a pure white colour, and was slightly agglutinated like spermaceti when a little of it was pressed between the fingers. It had a faint, disagreeable scent, like decaying fish, was of a light, feathery appearance, and decidedly crystallized. The form which it assumed was not unlike that which a drop of the solution of muriate of ammonia presents in crystallizing, when seen through a microscope. On closer examination the crystals proved to be four-sided prisms, and we were therefore certain it could not be nitrate of potash. Not having an opportunity for some months of making any further investigation, we found that during the time it had been laid aside it had contracted in bulk, which might have arisen either from a chemical change, or from its mechanical property of agglutination. The strong fishy scent was gone, but still the substance was slightly odorous.

We now determined to enter upon a thorough investigation of its nature and properties; but, as the whole quantity we possessed amounted only to a few grains, it was necessary that every experiment should be conducted in the most careful manner.

Our first experiments were to determine whether it

might not be nitrate of potash, whose crystalline form had been affected by some extraneous substance. For this purpose we placed a minute quantity on a strip of paper, and set fire to it. Now, if it had been nitrate of potash it would have slightly deflagrated as soon as the flame reached that part of the paper on which it was placed. The substance itself, however, caught fire, and whilst burning evolved a large quantity of free carbon. Another experiment proved that it would burn entirely away, and leave no residue. Litmus paper held in the flame was strongly reddened. To ascertain the nature of the acid that the litmus detected, a portion was burnt under a small glass tube, whose sides had been moistened with water, and a drop of muriate of silver discovered the presence of muriatic acid. These simple experiments proved the substance to be a CHLORIDE OF CARBON.

This substance is of a white aspect, and feels like spermaceti, smells faintly, is lighter than water, but sinks in ether; its specific gravity being about 950. It is insoluble in water, but dissolves in four times its weight of ether at F. 60: boiling ether takes up a larger quantity, but deposits it again on cooling. It is a non-conductor of electricity; fuses at 250 F., and may be distilled without change at lower temperatures; slowly volatilizes, and may be sublimed from a water bath in beautiful feathery crystals, like snow. It is also soluble in alchohol and hot volatile oils. It burns with a yellow flame, fringed at the upper part with red, and at the lower with green. Sulphuric acid has no effect upon it in the cold, but with the aid of heat the mixture becomes black, and much sulphuric acid is given out. When sulphur or phosphorus are melted with it, chlorides of those substances are

formed, and carbon deposited, which has a metallic appearance. Potassium takes fire when heated with it, forming chloride of potassium, and carbon is deposited. In one instance this action was so energetic that the little tube in which it was performed suddenly burst, and was separated from the other apparatus with a loud detonation. On passing the vapour of this substance through a red hot tube, muriatic acid gas was disengaged, and carbon deposited; from this we were at first inclined to infer the existence of hydrogen in the compound, and therefore attempted to gain a more certain deduction. When fusing sulphur with it a minute quantity of sulphuretted hydrogen was detected, and by the action of sodium pure hydrogen was obtained. But, upon passing the vapour over red hot peroxide of copper, a chloride of that metal and carbon were the sole products; from which we inferred that, if hydrogen does exist in this substance, it is as an impurity. Iron, tin, and zinc, likewise decomposed it, chlorides being formed, and carbon deposited. Peroxide of mercury is changed into calomel, carbonic acid is given off, and carbon deposited. From these experiments we are inclined to suppose that, setting aside the existence of hydrogen in the compound, which is probably extraneous, it is composed of

Carbon, 2 equivalents.
Chlorine, 1.

The greater part of this substance is now in the possession of Dr. Turner, of the University of London. It may be remarked as a curious circumstance, that a subtance identical in composition, and similar in many points, to that we have described, was found many years since in a vitriol manufactory in Sweden, by M. Julin. We have

since narrowly examined the coast of the Isle of Sheppey, hoping to meet with a larger quantity, but from our want of success we are led to suppose that its production was incidental, and probably arose from the decomposition of fish. The chlorides of carbon are of very difficult formation, their production being entirely dependent on the solar rays. The complicated changes, therefore, through which the elements of this substance must have passed are astonishing. We have no hesitation in pronouncing it the most singular and interesting specimen of natural history that we have seen; and the place in which it was found yields, we think, more sources of scientific inquiry than any spot at any equal distance from the metropolis.

A CATALOGUE OF THE FOSSILS

COLLECTED FROM

THE CHALK OF KENT.

CLASS.	GENUS.	SPECIES.	REFERENCES.
Agamia.	Confervites	fasciculata.	Ad. Brong. Hist. Veg. Foss. pl. 1. fig. 1.
——	——	undetermined.....	Mantell's Geol. Suss. pl. 9. f. 12.
Polypi.	Flustra	utricularis.[a]	Lam. Hist. Nat. Anim. sans vert. II. 224.
——	——	carbasea ?........	
——	——	undetermined.....	
——	Caryophyllia	prolifera.[b]........	Geol. Suss. Tab. 16. f. 2. 4
——	——	cyathus..........	Parkin. Org. Rem. vol. II. pl. 4. f. 6.
——	Spongia	ramosa...........	Geol. Suss. Tab. 16. f. 11.
——	——	lobata.	Park. Org. Rem. vol. II. pl. 7. f. 6.
——	Spongus	Townsendi.	Geol. Suss. Tab. 15. f. 9.
——	——	labyrinthicus.	Ibid. Tab. 15. f. 7.
——	Alcyonium	ramosa...........	Ibid. Tab. 15. f. 11.
——	——	digitata......... .	Ellis Coral Tab. 32.
——	Choanites	subrotundus.	Geol. Suss. Tab. 15. f. 2.
——	——	Königi.	Ibid. Tab. 16. f. 19. 21.
——	——	flexuosus.	Ibid. Tab. 15. f. 1.
——	Mantellia	radiatus.[c]......	Geol. Suss. Tab. 10. 11. 12. 13.
——	——	alcyonoides.......	Smith's Strata Tab. 3. f. 1.
——	——	quadrangularis. ..	
——	——	Benettiæ.	Geol. Suss. Tab. 15. f. 3
——	——	undetermined.[d] ..	

[a] A specimen of carbonized wood was also found in the same pit.

[b] Centralis of Mantell.

[c] Also called ventriculites, but their great investigator deserves the honour which has been given him.

[d] This differs from M. radiatus in the radii, which are much smaller.

CLASS.	GENUS.	SPECIES.	REFERENCES.
Radiaria.	Apiocrinites	ellipticus.	Park. Org. Rem. vol. II p. 13. f. 31. 34. 75.
———	Marsupites	Millери.	Geol. Suss. Tab. 16. f. 6.
———	Pentacrinites.	Caput Medusæ. ..	Miller's Crin. p. 46. pl. 1. 2.
———	Pentagonaster	seminulatus. ..	Park. Org. Rem. vol. III. p. 1. f. 1.
———	———	rectus.[e]	
———	Cidaris	cretosa.[f]	Park. Org. Rem. vol. III. p. 4. f. 3.
———	———	corollaris.........	Geol. Suss. Tab. 17. f. 2.
———	Echinus	saxatilis.	Park. Org. Rem. vol. III. p. 3. f. 1.
———	———	Königi.[g]	Ibid. vol. III. p. 1. f. 10.
———	Spatangus	cor-anguinum.....	Ibid. vol. III. p. 3. f. 11.
———	———	planus.	Geol. Suss. Tab. 17. f. 9. 21.
———	———	rostratus.	Ibid. Tab. 17. f. 10. 17.
———	Conulus	albogalerus.......	Ibid. Tab. 17. f. 8. 20.
———	———	subrotundus.	Ibid. Tab. 17. f. 15. 18.
———	Ananchytes	scutatus.[h]	Park. Org. Rem. vol. III. p. 2. f. 4.
———	———	ovatus.[g]	Desc. Geol. Env. de Paris, p. 5. f. 7
———	———	hemisphæricus. ..	Ibid. p. 5. f. 8.
Crustacea.	Astacus	undetermined.[i] ..	
Annelides.	Serpula	ampullacea.......	Min. Con. Tab. 596. f. 1.
———	———	obtusa [j]	
———	———	plexus.	Min. Con. Tab. 598. f. 1
———	———	circularis.........	Ibid. Tab. 608. f. 8.
———	Vermilia	umbonata	
Cirripeda.	Pollicipes	sulcatus	Geol. Suss. Tab. 33. f. 11.
———	———	maximus.........	
Conchifera.	Fistulana	personata.[j]	Geol. Suss. Tab. 18. f. 23.
———	Innoceramus	Cuvieri	Ibid. Tab. 27. f. 4.
———	———	Brogniarti.	Ibid. Tab. 27. f. 8.

[e] Rare.

[f] The cidari are very rare in the chalk of Kent.

[g] But one specimen, a remarkably fine one, in flint.

[h] These are among the most abundant fossils of the chalk.

[i] Very rare and imperfect.

[j] Very rare in Kent.

CLASS.	GENUS.	SPECIES.	REFERENCES.
Conchifera.	Innoceramus	Lamarckii.	Geol. Suss. Tab. 27. f. 1.
——	——	mytiloides.	Ibid. Tab. 28. f. 2.
——	——	cordiformis.......	Min. Con. Tab. 440.
——	——	striatus..........	Geol. Suss. Tab. 27. f. 5.
——	——	undulatus.	Ibid. Tab. 27. f. 6.
——	Plagiostoma	spinosum..... ...	Ibid. Tab. 26. f. 10.
——	——	Hoperi.	Ibid. Tab. 26. f. 2. 3. 15.
——	——	Brightoniensis. ..	Ibid. Tab. 26. f. 15.
——	Pecten	nitidus.	Ibid. Tab. 26. f. 4. 9.
——	——	quinquecostatus.[k]	Ibid. Tab. 26. f. 14. 20.
——	——	undetermined (3 species)........	
——	Dianchora	lata.[l]	Geol. Suss. Tab. 26. f. 21.
——	——	obliqua..........	Ibid. Tab. 25. f. 1.
——	Ostrea	vesicularis.	Desc. Geol. Env. de Paris, p. 3. f. 5.
——	——	semiplana.	Min. Con. Tab. 489. f. 3.
——	——	obliqua...	
——	——	————[m]	
——	——	————.........	
——	——	canaliculata.	Min. Con. Tab. 135. f. 1.
——	Terebratula	subrotunda... ...	Ibid. Tab. 15. f. 1. 2.
——	——	carnea.	Ibid. Tab. 15. f. 5. 6.
——	——	ovata.............	Ibid. Tab. 15. f. 3.
——	——	undata.	Ibid. Tab. 15. f. 7. 8. 9.
——	——	intermedia.	Ibid. Tab. 15. f. 8.
——	——	semiglobosa.	Ibid. Tab. 15. f. 9.
——	——	elongata.	Ibid. Tab. 435. f. 1. 2
——	——	plicatilis.	Ibid. Tab. 118. f. 1. 2.
——	——	subplicata.	Ibid.
——	——	octoplicata.	Ibid. Tab. 118. f. 2.
——	——	striatula.	Ibid. Tab. 536. f. 3. 5.
Mollusca.	Trochus	Basteroti.[n]	Desc. Geol. Env. de Paris, p. 3. f. 3.
——	——	unnamed.........	
——	Cirrus	depressus.........	Min. Con. Tab. 428.

[k] Very rare.
[l] Rare.

[m] Closely resembles the Ostrea edulis.
[n] Rare.

CLASS.	GENUS.	SPECIES.	REFERENCES.
Mollusca.	Cirrus	Perspectivus.	Min. Con. Tab. 428.
——	——	granulatus.	Geol. Suss. p. 195.
——	Dolium	nodosum.	Ibid. Tab. 426.
——	Belemnites	mucronatus.......	Ibid. Tab. 600. f. 1.
——	——	granulatus.	Ibid. Tab. 600. f. 3. 5.
——	Baculites	Faujasii.	Ibid. Tab. 592. f. 1.
——	Ammonites	varians...........	Ibid. Tab. 21. f. 2. 5. 7.
——	——	catinus..........	Ibid. Tab. 22. f. 10.
——	Scaphites	striatus...........	Ibid. Tab. 22. f. 3. 4.
——	Hamites	armatus.	Ibid. Tab. 23.
Pisces.	Murœna	Lewesiensis.	Ibid. Tab. 39. f. 11.
——	Zeus	——————......	Ibid. Tab. 35. f. 36.
——	Salmo	——————°	Ibid. Tab. 38. f. 40.
——	Esox	——————... ..	Ibid. Tab. 41. f. 1. 2.
——	Squalus	Cornubicus.......	Ibid. Tab. 32. f. 1.
——	——	Mustelus.	Ibid. Tab. 32. f. 2. 3. 6.
——	——	Zygœna.	Ibid. Tab. 32. f. 4. 7. 8.
——	——	Galeus.	Ibid. Tab. 32. f. 12. 14. 15.
——	——	3 species—undescribed...	
——	Diodon	undescribed......	Geol. Suss. Tab. 32. f. 18. 20.

° I have only found one specimen, which was a fine remain of scales and bones.

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DESCRIPTION OF THE PLATES.

PLATE I.

Fig. 1.—Representation of a Series of Stratified Rocks.
2.—Ditto Saddle-shaped Stratification.
Ditto Basin-shaped Stratification.
3.—Ditto Natural Section of Rocks.
4.—Ditto three different Series of Rocks disturbed by internal forces.
5.—Ditto Valley of Elevation.

PLATE II.

Fig. 1.—Representation of a Valley of Denudation.
2.—Ditto, Series of Rocks, in which three Geological Periods may be distinguished.
3. The Island of Stromboli.

PLATE III.

Fig. 1. Section of Rocks at Dartmoor to the Coast of Cornwall.
2. Headen Hill, Isle of Wight.
3. Rocks at Hordwell Cliff, Isle of Wight.

PLATE IV.

Fig. 1. Section of the Rocks from Harrow-on-the-Hill to Newhaven.
2. Section of the Rocks from near Leicester to Chalk-hills near Ivinghoe.
3. Section of the Oolite Series of Rocks.

PLATE V.

Fig. 1. London and Plastic Clay in their position Alum Bay.
2. Section of the Carboniferous Group and associated Beds, between the Mendip Hills and Fog Hill, near Lansdown.
3. Section of the same Group, between Pendle Hill and Holme Moss.

Pl. II

Fig 1

Fig 2

Fig 3

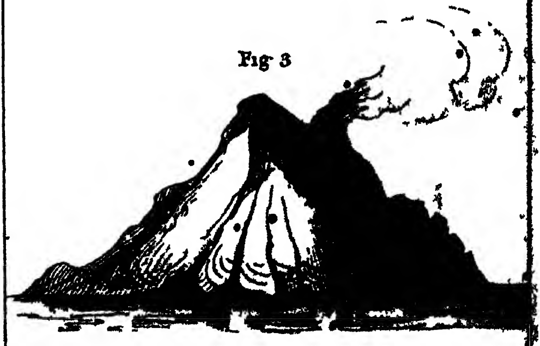


Fig 2

Section of Rocks at Headon Hill Isle of Wight

Fig 3

Section of the Lower Freshwater Strata in Barton Beacon and Hordwell Cliffs.

1 Diluvium
2 Sand Marle
3 White Sand
4 London Clay
5 Green Marles
6 Green Marles Light Colour
7 Sand Marle

D

E. Dyas, 8 Paternoster Row

Fig 1.

...ction of Rocks at Dartmoor to Coast of Cornwall

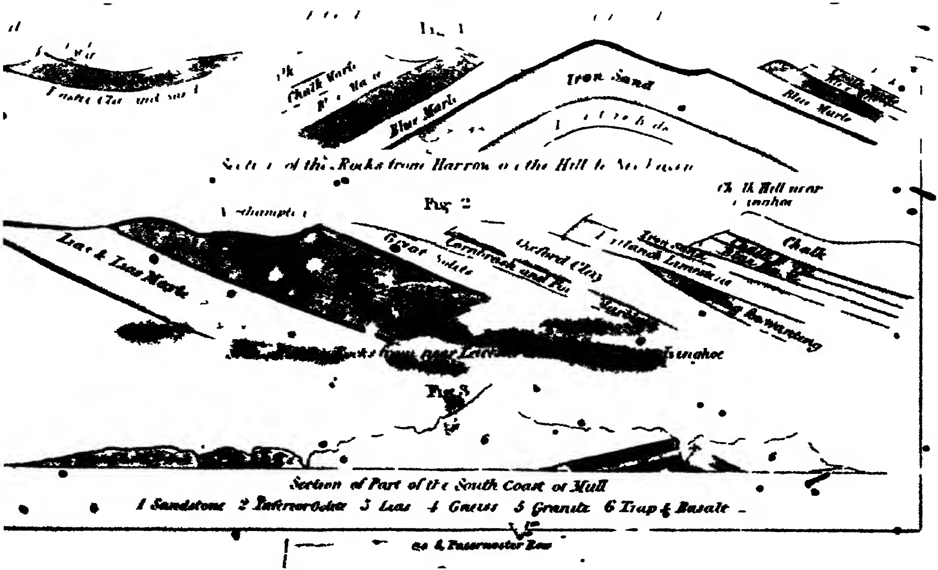
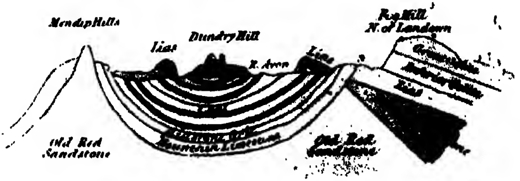

Chalk Marle
Blue Marle
Iron Sand
Blue Marle
Fig 2
Lias & Lias Marle
Great Oolite
Cornbrash and Fo
Oxford Clay
Iron sand
Chalk
Fig 3
Section of Part of the South Coast of Mull
1 Sandstone 2 InferiorOolite 3 Lias 4 Gneiss 5 Granite 6 Trap & Basalt
4 Paternoster Row

Fig. 1

Section of Rocks at Alum Bay, Isle of Wight.

Fig. 2



Section of the Rocks from the Mendip Hills to Pen Hill.

Fig. 3.

Section of the Rocks from Pendle Hill to Holme Moss.

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